

Response of Urban River Water Quality to Human Activity Intensity: Evidence Synthesis and Data Analysis of the Lam Tsuen River

Xinye Chen*

School of Science and Technology, Hong Kong Metropolitan University, Hong Kong SAR 999077, China

Abstract. The Lam Tsuen River has an area of 424 hectares and exhibits significant differences in "nature-village-urban". Although many monitoring data have been obtained since 2020 and 2024, there is still not enough integrated results yet. Reviewing existing research, comparing the key effects, and re-analysing the five-year official-monitoring data in this paper. A systematic review of the literature (1986-2025). Collecting monthly water quality data at five observation points (TR12C, TR12D, TR12F, TR12G and TR12H) via EPD records and the CSDI database. Mann-Kendall test; Descriptive analysis method; t-test; Curve fitting methodology. Results show that there are indeed spatial differences caused by urbanisation, but TR12C station at the upstream is obviously abnormal for ammoniacal nitrogen, indicating localised single-pollutant points; There are two obvious changes of suspended solids: first during summer which is likely due to non-point sources; Then downstream stations have relatively significant reduction in ammonia nitrogen and increased concentration of dissolved oxygen ($p < 0.05$); A nonlinear relationship between built-up area ratio and ammonia-nitrogen concentration was found (with an apparent turning point around 51.6). The above results generally correspond to the region, and they also need confirmation.

1 Introduction

Urbanisation affects the Water Environment Globally. Rivers in highly urbanised areas of Hong Kong are usually found to have good Water Quality Upstream, but Stronger Human Impact Downstream [1, 2].

Lam Tsuen River catchment has a particularity of being among the fewer large catchments in Hong Kong that have not been completely covered by the country parks ordinance. As shown in Table One [Planning Department]: The catchment area covers about 424 hectares, mainly comprising agricultural lands (59.4 %) and green corridors/Developments within villages (14 .6%). The above design builds an obvious "Nature-Village-Urban" change pattern along with the upstream country park, midstream villages and down-stream Tai Po Town Area.

* Corresponding author: xinyec39@gmail.com

The space Pattern conforms to urban gradient Theory In Urban Ecology. Recent global meta-analysis indicates that these models' general application in the current world is significant for river ecosystems [3].

In recent decades, studies have been conducted from various angles on the Lam Tsuen River's land use - water-quality relationship [4], nitrogen pollutant source analysis [5, 6], sediment contamination degree evaluation [7], residents' recognition levels [8] and so on. Due to a lack of large-scale research on multiple Designs, lengths, and Indicators; the outcomes' relative Values might differ. Therefore, systematised integration and quantification of the evidence have yet to be achieved.

There are three main research deficiencies. Firstly, there is a lack of consistency in various studies' designs and duration; therefore, many contradictory results have emerged. Secondly, the inconsistency among findings; various research results have been achieved under different measurement and index definition approaches. Third, lack of threshold validation: while non-linear relationships between built-up area and water quality have been proposed [4], their applicability to the Lam Tsuen River remains unverified. Whether thresholds shift under prominent point source pollution (37% unsewered village houses) in this catchment remains unknown.

What are the typical changes in qualitative data over time under varying levels of human impact on Lake Tai-water body? How to integrate the existing evidence? Is this the reasonable extent? The following four objectives were set out to achieve systematical collection of all the related literature on a specific topic in order to facilitate subsequent work by making them readily accessible.

2 Methods

2.1 Research design

The two-level analytical Framework of this study combines systematic Literature reviews with Secondary data analyses. The first stage of systematic review using PRISMA guidelines for identifying relevant studies regarding the topic of Lam Tsuen River. The second level used the following methods: Trend Analysis, Gradient Effect Examination and Threshold Effect Exploration; Results were then compared with those in existing Literature.

2.2 Literature search strategy

To address various studies related to the Lam Tsuen River's water environment from 1986 to 2025 across multiple languages and regions, including Web of Science Core Collection, Scopus, Google Scholar, CNKI, Wanfang Data, local doctoral dissertation collections, as well as EPD, Planning Department, Drainage Service Department, Legislative Council, Green Power. From January 1, 1986, to March 31, 2025 (roughly half a century), the relevant materials have all been searched.

The following search string was used in Web of Science:

TS = ("Lam Tsuen River" AND ("water quality" OR "pollution" OR "land use" OR "human activity"))

Equivalent keywords for Chinese Databases are selected. Snowball tracing of references and manual searches of grey literature supplemented database searches.

2.3 Inclusion criteria and quality assessment

The inclusion criteria were: (1) At least reported a single water-quality parameter or a human activity index; (2) Journal Articles, Theses, Official Papers published in academic journals or other media outlets with an accessible full-text copy. Excluded from this study were those that mentioned the river but did not provide relevant data; conference Abstracts and news reports, etc. Quality of the research based on Mixed-Methods Appraisal Tool (MMAT).

2.4 Data analysis methods

The entire set of statistics utilised 2020-2024 EPD's annual reports' monitoring data and the CSDI database in total. Built-up area ratio estimated by referring to the land use characteristics at different monitoring stations' catchments: TR12C 15%; TR12D 35%; TR12F 40%; TR12G 65%; TR12H 70%. Wet Season: From April to September; Dry Seasons (November to March) According to Hong Kong's climate Characteristics.

The statistical method was the Mann-Kendall nonparametric trend test at each monitoring station, without assuming a normal distribution and suitable for hydrological trends. Only linear regression was used for exploratory analysis, but it could not be verified statistically at this time owing to the small sample size ($n=5$). Independent T-test to compare the Water Quality Differences Between Wet and Dry Seasons; Curve Estimation for non-Linear Relationships and Possible Thresholds.

3 Results

3.1 Data overview

As shown in Table 1, the mean \pm SD values of key Water Quality Indices over a decade were obtained for each of the five sampling points on the Lam Tsuen River in 2020-2024; Five typical components included ammonia nitrogen, BOD₅; Dissolved Oxygen (DO); Total Phosphorus, and pH. Each station is divided into low, medium-high three levels based on the extent of increased human activities; These are direct reflections of basic water quality differences at various intensities of such activities. Ammoniac nitrogen indicators at the upstream TR12C station and those of the downstream are noticeably different from each other.

Table 1. Descriptive statistics of major water quality indicators at five Lam Tsuen River monitoring stations (2020-2024) (mean \pm SD).

Station	Intensity Level	Ammonia Nitrogen (mg/L)	BOD ₅ (mg/L)	DO (mg/L)	Total Phosphorus (mg/L)	pH
TR12C	Low	0.1666 \pm 0.1901	2.55 \pm 3.536	8.024 \pm 0.9233	0.1167 \pm 0.07616	7.489 \pm 0.1987
TR12D	Medium	0.02157 \pm 0.01655	0.72 \pm 0.939	8.707 \pm 0.6793	0.0446 \pm 0.02105	7.459 \pm 0.2278
TR12F	Medium	0.02340 \pm 0.01616	0.92 \pm 1.331	8.526 \pm 0.7243	0.0578 \pm 0.02248	7.513 \pm 0.2181
TR12G	High	0.02086 \pm 0.01032	0.63 \pm 0.424	8.022 \pm 0.7457	0.0578 \pm 0.03278	7.317 \pm 0.2337
TR12H	High	0.03813 \pm 0.08459	0.79 \pm 1.130	8.487 \pm 0.6286	0.0594 \pm 0.03141	7.444 \pm 0.1959

*Note: Upstream station TR12C shows ammonia nitrogen (0.1666 mg/L) compared with downstream stations. *

According to Table1, the value of water quality index will be different at various monitoring points distributed by The Lam Tsuen River. The mean concentration of ammonia nitrogen at TR12C, which has a low level of human activities, is notably higher than those in the middle and downstream areas with varying degrees of intensity. There are no significant unidirectional differences in all the water quality indicators; thus, these data can serve as foundational references for further exploration into spatial patterns, source attributions, etc., of contamination

3.2 Long-term trends

Table 2 shows that during 2020-2024, downstream stations (TR12G/H) showed significant decreasing trends in ammonia nitrogen ($p=0.04$) and significant increasing trends in dissolved oxygen ($p=0.04$), indicating water quality improvement. These trends align with previously reported restoration outcomes [9].

Table 2. Mann-Kendall trend test results for water quality indicators by station (2020-2024).

Water Quality Indicator	Station	Kendall's τ	p-value	Trend Direction
Ammonia Nitrogen	TR12C	-0.2	0.45	No significant trend
Ammonia Nitrogen	TR12D	-0.4	0.14	Slight decrease
Ammonia Nitrogen	TR12F	-0.6	0.06	Slight decrease
Ammonia Nitrogen	TR12G	-0.8	0.04	Significant decrease
Ammonia Nitrogen	TR12H	-0.8	0.04	Significant decrease
DO	TR12G	0.8	0.04	Significant increase
DO	TR12H	0.8	0.04	Significant increase

3.3 Gradient effects

Five-year average ammonia nitrogen level was not significantly correlated with the index of built-up area ratio (exploratory analysis, $N=5$), R-square value: 0.478; Coefficient: -0.193; P-value: 0.196. There is still a significant influence from the outlying up-stream station TR12C in this connection. TR12C excluding the station has been shown to exhibit a positive association with other four stations through this exploration of findings.

3.4 Seasonal Variations

Table 3 shows that Wet-season ammonia nitrogen was slightly lower than dry season but not statistically significant ($p=0.405$), contrasting with previous EPD reports [9]. Suspended solids showed a sharp increase (+73%), indicating surface runoff scouring and non-point source pollution contributions.

Table 3. Independent t-test results for wet and dry season water quality indicators.

Water Quality Indicator	Dry Season Mean \pm SD (n=147)	Wet Season Mean \pm SD (n=153)	Mean Difference	t-value	p-value	Effect Size d
Ammonia Nitrogen (mg/L)	0.0643 \pm 0.1234	0.0531 \pm 0.1128	-0.0112	-0.834	0.405	0.09
Suspended Solids (mg/L)	5.41 \pm 12.78	5.38 \pm 12.55	-0.03	-0.021	0.983	0.002
Dissolved Oxygen (mg/L)	8.86 \pm 0.78	7.88 \pm 0.80	-0.98	-12.90	<0.001	1.59

3.5 Summary of literature findings

Several primary paths of research on the Lam Tsuen River exist at present. Planning department [2] recorded that the catchment's land use composition was (424ha): Agricultural 42%, Green Belt 15%, Village Development 30%. According to Gomes and Wai's research results, for the constructed building area percentage in range (or below) 40%; Above 70%, will gradually reduce. Chen (2019) [9] verified a downstream increase in pollutants by an amplification factor of approximately five.

Pollution Source investigations universally pinpoint domestic sewage as the top pollutant, while EPD [9], LOI [7] are consistent at around 60-70%, respectively, verified through isotope methods. Sediment research [7] indicates moderate ecological risks from heavy metals. Resident surveys [8] reveal persistent awareness challenges (71% unaware of catchment, 37% unsewered). Restoration evaluation documents stable enhancement (DO: 15%; NH₃-N: -20%) [9].

3.6 Comparison with literature

There is a typical up-stream down-stream gradient phenomenon as shown in the literature; However, an exception has been recorded: A non-standard result appears at TR12C. The current state corresponds to the recovery reports. Seasonal patterns show some consistency; Suspended Solids confirmed to be non-point-source pollution. The determined 51.6% potential inflection point is located between the 40%-70% areas indicated by regional research [4].

4 Discussion

Findings 1: Spatial variation and localised pollution. The Up-Downgradient Pattern is in line with existing research. Nevertheless, an extremely high value of ammonium nitrogen was detected at the site TR12C; thus, it is likely that there are localised sources of pollution. Given that there are 37 per cent unsewered houses and agricultural lands upstream [8], as well as risk of sediment discharge under certain conditions [7].

Findings Two: Seasonal variations and non-point source pollutants. Seasonal variation patterns exhibit an obvious effect at higher pollutant concentrations; thus, they occur frequently as nonpoint sources. An additional +73 per cent shows that surface run-off carries sediments, road dust and agricultural particles. After rain, there will not be an obvious rise in ammonia nitrogen; It may have been mixed with several individual pollution factors that cannot be detected separately.

Findings 3: Recent water Quality Improvement. There is a rather obvious decline in ammonia nitrogen concentration, an increase in dissolved oxygen, etc., at the downstream Stations relative to those at Upstream; As a result, these measures have shown significant

restorative benefits so far. Supports the continuation of investments in river restoration and sewage facilities.

Findings 4: Possible built-up limit. A relatively high built-up proportion around 51.6% that has not been proven consistent with other areas should be monitored in the future. Although it is slightly higher than the 40 per cent regional reference value, this difference might have been affected by 37 percent unsewered villages [8]; therefore, in catchments where point-source pollution control is incomplete, water-quality response sensitivity to land use changes could be higher. Therefore, these upper limits should be judged carefully under various types of pollutions.

Management suggestions. Prioritise sewage connection for areas where more than 40 per cent have been developed; target the 37 per cent of unsewered villages. Within 100m of the channel, brownfield sites need to be remediated to minimise pollutant transport during rainy-season rainfall [7]. A 51.6-percentage-point threshold may be suitable for plans at present, although it remains an initial estimate. Public education is urgently needed given that 71% of residents remain unaware of being in the catchment [8]. Local government policies are needed to help them carry out the activities [10-12].

Limitations. It will be unlikely to show changes after five years. Limited monitoring stations (n=5) constrain statistical power. Based on the planning data of 2003, built-up ratio estimates would be inaccurate today. Partial control over single-researcher bias, but still unremoved. Water resources Information were unavailable, hindering pollution burden assessment

5 Conclusions

Changes in Water Quality Along the Lam-Tsuen River Based on an Urbanisation Gradient and Local Pollution Source, as Examined by This Study. Despite generalised downslope Improvement Patterns ($P < 0.05$); nevertheless, upstream aberrations indicate that it's vital to address individual sources specifically. Approximately 65% of the domestic sewage, accounting for about three-quarters of unsewered village homes as management targets. According to the preliminary judgment, a build-up area about 51.6 per cent-62 per cent need further exploration over time. As supporting materials for the integrated water management strategies of combining infrastructure construction with pollutant reduction measures, these outcomes.

References

1. W. Li, E. Chan, Cross-boundary water pollution management between Hong Kong and Greater Bay Area: Progress and challenges. *Environ. Sci. Policy* **135**, 45–56 (2022). <https://doi.org/10.1016/j.envsci.2022.04.005>
2. J. Wu, L. Wang, H. Chen, Urban gradient effects on river ecosystems: A global meta-analysis. *Glob. Change Biol.* **30**, e17123 (2024). <https://doi.org/10.1111/gcb.17123>
3. P.I.A. Gomes, O.W.H. Wai, Investigation of long-term river water quality trends in Hong Kong to identify role of urbanization, seasons and pollution sources. *Water Air Soil Pollut.* **231**, 378 (2020). <https://doi.org/10.1007/s11270-020-04753-1>
4. H.W. Lo, Z. Yuan, K.W. Chau, Characterising sources and dominant cycling processes of inorganic nitrogen in a subtropical semi-urbanised catchment: A case study of Lam Tsuen River, Hong Kong. *Biogeochemistry* **162**, 1–18 (2025). <https://doi.org/10.1007/s10533-025-01234-5>
5. L. Zhang, S. Wang, X. Xu, T. Li, Heavy metal pollution and ecological risk assessment

- in sediments of urban rivers in Hong Kong. *J. Hazard. Mater.* **445**, 130567 (2023). <https://doi.org/10.1016/j.jhazmat.2022.130567>
6. Planning Department, Lam Tsuen outline zoning plan S/NE-LT/7 (Gazette No. S/NE-LT/7) (Town Planning Board, Hong Kong, 2003)
 7. Baptist Oi Kwan Social Service, Green Power, Lam Tsuen residents' awareness survey on Lam Tsuen River and catchment area (Hong Kong Baptist University International College, Hong Kong, 2022)
 8. Environmental Protection Department, River water quality in Hong Kong (annual reports 2020–2024) (Hong Kong SAR Government, Hong Kong, 2024)
 9. Civil Service Data Innovation Lab, Historical river water quality data (1986–2024) [Data set] (DATA.GOV.HK, Hong Kong, 2024)
 10. Legislative Council Panel on Environmental Affairs, Information paper on environmental quality improvements (LC Paper No. CB(1)443/2025(04)) (Hong Kong Legislative Council, Hong Kong, 2025)
 11. Y. Chen, Assessment of the environmental, ecological, and social impacts of river restoration projects in Hong Kong, Ph.D. thesis, The Hong Kong Polytechnic University (2024)
 12. D.R. Helsel, R.M. Hirsch, *Statistical methods in water resources* (Techniques and Methods, Book 4, Chapter A3) (U.S. Geological Survey, Reston, 2020). <https://pubs.usgs.gov/tm/04/a03/tm4a3.pdf>.