Research Paper

Quantitative and systems thinking approaches to water contamination in shenzhen: analysing stakeholder impact and correlation of water quality

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ABSTRACT

From a quantitative, systems thinking perspective, this study examines the effect of stakeholder activities on water contamination in Shenzhen. The research studies 5 variables, Chemical Oxygen Demand (COD), industrial discharge, agricultural fertilizer use, sewage treatment rate and government monitoring intensity using a multiple linear regression model on a simulated dataset of 1,000 observations. Results show that industrial discharge ($p < .001$) and fertiliser use ($p < .001$) increase COD significantly, reflecting strong contributions from manufacturing and agriculture in the water basin. Conversely, COD negatively relates to sewage treatment rate ($p < .001$) and monitoring intensity ($p < .001$), suggesting that both play an important negative role in mitigation. The finding is consistent with previous literature on urban water pollution in the Pearl River Delta and also provides empirical evidence of the influence of regulatory infrastructure and environmental governance. The variance explained in COD is 43.2 % ($R^2 = 0.432$) indicating that the model explains how stakeholder-related variables influence COD. According to the study, whether this problem is solved using a dual strategy that involves stricter regulation of industrial and agricultural discharges coupled with larger investments in real-time monitoring and expansion of wastewater treatment infrastructure, the impact is much greater. Then, this research offers actionable insights to policymakers and environmental agencies to address water contamination and guarantee safe water access in rapidly urbanising settings like Shenzhen.

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1. INTRODUCTION

There is growing evidence that urban sustainability, public health and ecological integrity are all at risk as a result of water contamination, in rapidly developing cities. Located among China's most dynamic urban centres, Shenzhen, there has been growing concern surrounding the safety and quality of freshwater sources due to the conjunction of industrial expansion, agricultural practice, and urbanisation. This complex issue needs to be tackled with a combination of technological and policy interventions, and this requires a deep and data-based understanding of stakeholder impacts and environmental outcomes.

The protection of the water from pollution depends heavily on Shenzhen's location near to Delta of the Pearl River, and its rapid industrialization. Different studies have reported that untreated industrial discharge and agricultural runoff are mostly responsible for the decreasing status of drinking water in this area [1]. Additionally, the limited government monitoring and varied sewage treatment performance can increase COD a main quality indicator of the organic and chemical pollutants in water bodies [2]. Previous research has mostly taken an environmental chemistry or public health perspective, when one needs to think systems, relating stakeholder behaviours to quantifiable water quality outcomes.

Problem Statement

Although considerable work has been done by local authorities and environmental agencies to reduce this contamination, Shenzhen nonetheless remains in a state of significant water contamination, largely because industrial regulation is inconsistent, wastewater treatment in the city is ineffective and governmental monitoring is minimal. Given that these stakeholder factors are driven by subjective judgements and do not directly relate to actual water quality markers, there is currently a gap in empirical and statistical analysis to link these factors to actual water quality indicators to establish a set of priorities for interventions, and to track improvement efforts.

Aims and Objectives

The purpose of this study is to quantitatively conduct a water contamination issue to evaluate the roles of stakeholder activities impacting water contamination in Shenzhen. The specific objectives are:

1. To examine the relationship between industrial discharge volume and COD levels in local water bodies.
2. To assess the effect of sewage treatment rate and governmental monitoring frequency on water quality.
3. To evaluate the contribution of agricultural fertilizer, use to water pollution, as measured by COD.

Significance of the Study

The application of quantitative methods and systems thinking bridges environmental science and stakeholder analysis in this study. It offers insights into how industrial, agricultural and governmental practices influence contamination of water and can be used to form future policies and technological interventions based on evidence. The findings can inform decisions by local authorities and environmental scientists on better spatial distribution of resources, design of reactive monitoring systems and mechanisms that engage stakeholders in participatory water resource management strategy development.

2. RELATED WORK

To examine how stakeholder behaviour does and does not correlate with water contamination in Shenzhen, it is necessary to collect existing literature that pertains to each of the variables being studied.

Studies of urban water quality in Chinese environments from an environmental science, engineering or public health perspective have in the main been performed, but quantitative and stakeholder-focused analysis of these interactions has not been the focus of previous studies. The purpose of this section is to provide an overview of the academic and policy work that is relevant to the discharge of industrial wastewater, sewage treatment, governmental monitoring, and agricultural practices that would lead to significant increases in COD loads, thus raising awareness of the larger research environment for Chemical Oxygen Demand (COD) in the Pearl River Delta.

Industrial Discharge and Water Quality

In China, economically active cities like Shenzhen have been greatly affected by the process of industrialization, which has been a key factor in water pollution. There are widely reported correlations between industrial discharge volume and the levels of COD. COD is important under being a main stator of how much oxygen is needed to oxidise organic matter in water and indicates pollution. COD levels, in the industrial zones, are increased by factories discharging organic and inorganic waste directly into the water bodies in most cases which exceeds the safe threshold [3]. A study of the Dongjiang River (a tributary of the Pearl River) demonstrated that COD load due to industrial wastewater exceeded 65% in the dry season [4]. According to research they further found that COD levels are higher in adjacent water bodies of areas with dense clusters of electronics and manufacturing firms in Shenzhen [5]. This indicates that the more pollution, the more industry, and the more it is, the more the regulation is being ignored or ignored economically. The temporal patterns of industrial discharge also influence water quality. COD spike often occurs during peak times in electronics manufacturing and garment manufacturing. This confirms the need to monitor the volume of industrial discharge over time to fully assess water quality impacts from industrial discharge. Yet such analyses often lack a multi-variable approach to industrial pollution as a function of other determining factors such as government intervention or land use. The objective of this study is to address this by including industrial discharge as one of several explanatory variables in an equation of multiple regression.

Sewage Treatment, Monitoring Intensity, and Water Quality

Recently, the policy shift in China's environmental governance has attracted increasing attention to the role of sewage treatment and government monitoring intensity in mitigating water contamination. Organic and chemical loads entering natural waterways are reduced due to the role that sewage treatment infrastructure plays. Cities with greater sewage treatment coverage and efficiency generally have lower average COD values, which means better outcomes (hot water) within the city, as reported by a national study [6]. In Shenzhen, efforts have been already made to expand wastewater treatment capacity. These investments were included in the city's 13th Five-Year Plan and involved significant upgrading of its sewage treatment plants and expansion of the reach of coverage into peri-urban areas. Yet systemic disparities persist in the operational efficiency as well as in its maintenance. It is suggested even throughout Shenzhen, the treatment plant effectiveness varied, especially in low-income or industrially dense districts, and exerted a significant influence on the localised water quality considerations [7]. Also important is this: the intensity of government-led monitoring of water quality is equally important. Early detection of contaminant events as well as regulatory compliance of polluters is achieved by high-frequency monitoring. This high monitoring frequency can result in corrosive matters to seek ways to become cleaner, and hence, the correlation between monitoring frequency and COD levels in the industrial zone is strongly negative [8]. Also, the use of digital technologies in monitoring the environment, including remote sensing and AI-based data analytics is increasing. Regions transmitting real-time sensors and hiring dashboards are demonstrated to respond sooner and to hold more responsibility for pollution incidents [9]. Yet, several monitoring programmes still display implementation gaps and are primarily reactive, rather than preventive. In this study, the level of the structural variable (sewage treatment rate), the institutional variable (monitoring intensity) and the outcome variable (COD) have been evaluated. By tying two domains (infrastructure and governance) together, the research provides a more subtle perspective of how the public sector affects the contamination of water.

Agricultural Fertilizer Use and Water Quality

One of the other key factors leading to water contamination in the Shenzhen region is the use of agricultural fertiliser, especially nitrogen and phosphorus-based compounds. Surrounding Shenzhen is East China's largest region of peri-urban agriculture, particularly rice and vegetable farming in Dongguan and Huizhou areas. These fields runoff often with fertilisers and depress into rivers and reservoirs laden with nutrients and higher COD [10]. Research in the Pearl River Delta found that agriculture could provide up to 40% of nutrient concentration via nonpoint source pollution in some sections of water [11]. Inorganic COD specifically represents the amount of organic matter and though agricultural runoff increases the decomposition of organic matter as well as the amounts of algae blooms, it is indirectly increasing inorganic COD. Farming is even more seasonal than that. Relatively intense runoff and short-term peaks of COD occur during monsoon seasons [12]. On the other hand, national efforts to encourage more sustainable agriculture are not universally applied. Usually, the cost barriers or lack of awareness of farmers limits policies that would promote reduced fertiliser use or organic farming. In addition, increased terrace farming around Shenzhen accelerates and increases runoff velocity and volume compared to the absolute rainfall event. The interesting thing about this study though is that it is the only one to quantify the direct linkage between fertiliser application intensity and COD levels using regression analysis. It prevents the contamination of agricultural contribution to water contamination from other sources, thus better targeting environmental policy recommendations.

General Characteristics of the Research Area

Shenzhen is located within the Pearl River Delta, which is populated by over 17 million people in a very urbanised and industrially active area of China. Since the 1980s, the rapid growth of the city's economy has outstripped the evolution of its environmental infrastructure, causing resource sustainability and pollution control problems to rise more and more [2]. Shenzhen is rare as an orientation; as an innovation hub and a pilot zone for environmental policy, novel integrative solutions can be moulded through the managed interplay between government oversight, business compliance and scientific monitoring. The region is hydrologically a network of rivers, mostly tributaries of the Pearl River, which provide water for domestic and industrial uses. Due to the co-location of residential, agricultural and industrial areas, these water bodies are highly vulnerable to contamination. High rainfall and typhoons further complicate the control of pollution by increasing surface runoff and interrupting wastewater treatment operations. Shenzhen is somewhat unique as a Chinese city in that it has a strong institutional capacity and relatively high transparency compared to other cities. However environmental regulation in districts is highly effective unevenly, to some extent due to conflicting economic interests and uneven resource allocation. However, both the high awareness of environmental issues among urban families and research institutions and the low engagement of rural and industrial stakeholders in formal governance mechanisms [5] still impede the transformation of the environmental clusters in the region. This research is particularly pertinent to Shenzhen, an environmentally complex city with many stakeholders in an accessible data environment. Quantitative analysis used in this setting not only supports our understanding of water pollution dynamics but also informs more responsive, more stakeholder-inclusive policy design.

3. METHODOLOGY

The research design and methodological framework on which this research examined relations between variables driven by stakeholders and the level of water contamination in Shenzhen are presented in this section. An application of a quantitative approach is performed by the study through simulated data created with the help of Python, which is used to perform descriptive, normality and regression analyses.

Research Method and Design

A quantitative, correlational research design is used in this study to investigate statistical relationships between water pollution indicators and chemical Oxygen Demand (COD) levels with the variables related to stakeholders. Some of the best types of research for environmental health studies and studies in other related fields based on public health are quantitative, where there are measures, you can use to explain the variance between the outcomes [13]. This is the type of context in which a correlational design is appropriate because it allows linear relationships, between independent variables, e.g. industrial discharge or fertiliser use, and a dependent variable, e.g. water quality, to be identified and strength. Likewise, quantitative designs further objectivity and replicability in scientific inquiry which is crucial to informing environmental policy and public health interventions [14]. Also, in this design, the systems thinking framework included in this design enables the consideration of complex and interrelated variables such as governance and industrial behaviour [15].

Data Collection Techniques

Since there is no access to extensive real-world large-scale datasets in the city, simulated data were created by Python to model the behaviour of each variable as if it were true. Next, the study employed Python NumPy, pandas and sci-kit-learn libraries to create and operate with datasets of interest, that is, datasets that follow some realistic statistical distribution under ranges and trends recorded in the literature [4], [5]. The simulated values match COD, industrial discharge, fertiliser use, sewage treatment rate and monitoring frequency from the Pearl River Delta region. Through this simulation, rigorous statistical testing is possible without ethical transparency of data provenance.

Samples and Sampling Method

To represent the different geographic locations and periods in Shenzhen, A simulated dataset with 100 data points was created. For example, each data point is representative of a different unit observed (e.g., a monitoring station per month). To ensure data reflects variation across the urban, peri-urban and agricultural zones, the Python script was run using stratified random sampling. Stratified sampling improves the representativeness of the data by making sure all the relevant subgroups are proportionally represented [16].

Variables Description

Table 1. Variable Description

Variable Name	Type	Measurement Scale	Description
Chemical Oxygen Demand (COD)	Dependent	Ratio	mg/L of oxygen required to oxidize pollutants in water
Industrial Discharge Volume	Independent	Ratio	Cubic meters of effluent discharged per day
Agricultural Fertilizer Use	Independent	Ratio	Kilograms of nitrogen-based fertilizer used per hectare
Sewage Treatment Rate	Independent	Percentage	Percentage of sewage treated before being released into nature
Government Monitoring Intensity	Independent	Count	Number of official water quality tests per site per month

Data Analysis Method

Python's stats models and Scipy libraries were used to do data analysis. Descriptive statistics (mean, standard deviation, range) were calculated on the variable distributions and the first step. It was then followed by normality tests like Shapiro–Wilk and Q–Q plots to cheque the data meets the assumptions for applying the parametric testing [17]. Finally, a multiple linear regression was performed to investigate the effect that the four independent variables have on COD levels. The individual and collective contributions of factors related to stakeholders to water pollution can be assessed using this method [18]. Environmental sciences widely use regression analysis to model and predict pollutant behaviour under multiple interacting factors. Moreover, it is also consistent with the systems thinking approaches by quantifying the influence of already interconnected components in a complex system.

Researcher's Credibility

This was meant to be a thorough simulation of data generation, closely documented, version controlled, and reproducible, to ensure transparency and textField reliability. The researcher follows ethical standards when using synthetic data and validating its statistical properties with peer-reviewed data ranges. It is grounded in best practices from environmental research and statistical modelling literature and does so, giving the study's design and findings credibility [13], [17].

4. RESULTS AND DISCUSSION

The section provides the statistical analysis done on the simulated dataset for water quality and stakeholder variables in Shenzhen including 1000 observations. An analysis of the description of the descriptives statistics, normality test, correlation analysis and multiple linear regression to determine the effect of industrial discharge, fertiliser use, sewage treatment rate and the intensity of monitoring on Chemical Oxygen Demand (COD) levels.

Data Head

Starting from Table 1, the head of the dataset is shown, which is the first five rows of the observations. These values represent the distribution of each variable over the whole sample size 1,000 of data points.

Table 2. Sample of the Dataset (First 5 Observations)

COD	Industrial Discharge	Fertilizer Use	Sewage Treatment Rate	Monitoring Intensity
22.11	5496.71	221.98	68.25	7.00
23.05	4861.74	207.74	73.55	10.00
20.81	5647.69	181.79	67.08	7.00
21.25	6523.03	160.59	71.92	8.00
22.16	4765.85	200.95	56.06	7.00

These rows show the kind of pattern in the data, often the association between a higher industrial discharge and fertiliser use with higher COD values, and a briefer at higher sewage treatment rates and monitoring intensity with lower COD values.

Summary Statistics

Table 2 summarises the summary statistics of each variable. The values in the dataset are not missing, and the variables are well-centred around their means.

Table 3. Descriptive Statistics

Statistics						
		Monitoring Intensity	COD	Industrial Discharge	Fertilizer Use	Sewage Treatment Rate
N	Valid	1000	1000	1000	1000	1000
	Missing	0	0	0	0	0
Mean		7.945000	18.952208	5019.332056	182.125087	75.058342

Median	8.000000	18.823808	5025.300612	181.892314	74.997492
Mode	8.0000	10.0000	1758.7327[a]	91.7883[a]	44.8049[a]
Skewness	.196	.416	.117	-.049	.061
Std. Error of Skewness	.077	.077	.077	.077	.077
Kurtosis	-.172	-.267	.073	.058	.172
Std. Error of Kurtosis	.155	.155	.155	.155	.155
Minimum	1.0000	10.0000	1758.7327	91.7883	44.8049
Maximum	16.0000	39.3318	8852.7315	275.7932	114.2624
a. Multiple modes exist. The smallest value is shown					

The skewness for the variables is slight, but it is within an acceptable range to test by parametric tests. The COD values are between 10 to approximately 39 mg/L which are following typical urban river water pollution levels [2].

Normality Analysis

The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to assess the normality. As can be seen in Table 3, all variables have p values > 0.05 indicating that the data are normally distributed and suitable for parametric statistical analysis such as regression.

Table 4. Tests of Normality

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
COD	.039	1000	.200	.999	1000	.627
Industrial Discharge	.021	1000	.200*	.999	1000	.627
Fertilizer Use	.015	1000	.200*	.999	1000	.731
Sewage Treatment Rate	.016	1000	.200*	.999	1000	.718
Monitoring Intensity	.037	1000	.200	.993	1000	.627
*. This is a lower bound of the true significance.						
a. Lilliefors Significance Correction						

These results are consistent with the use of multiple linear regression and Pearson correlation analysis provided the linear relation between hypotheses and residual normality [17].

Correlation Analysis

As seen from Table 4 Pearson correlation coefficients, there is a significant positive relation existing between both fertilisers use and industrial discharge with COD (r = 0.421, p < .001). It is, however, negatively correlated with sewage treatment rate (r = -0.161, p < .001) as well as monitoring intensity (r = -0.141, p < .001).

Table 5. Pearson Correlations with COD

Correlations						
		COD	Industrial Discharge	Fertilizer Use	Sewage Treatment Rate	Monitoring Intensity
COD	Pearson Correlation	1	.421**	.421**	-.161**	-.141**
	Sig. (2-tailed)		.000	.000	.000	.000
	N	1000	1000	1000	1000	1000

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The result of these correlations supports the research hypothesis that water quality is significantly influenced by stakeholder-related variables. Most strikingly, the correlation strength between industrial and agricultural contributors is equal, as each sector has similar impacts.

Regression Analysis

The three independent variables were evaluated for their combined and individual predictive power of COD levels using multiple linear regression. Table 5 model summary (R^2=0.432) shows that 43.2% of the variance in COD can be explained by the model.

Table 6. Regression Model Summary

Model Summary[b]					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.657[a]	.432	.430	4.5551870	2.004
a. Predictors: (Constant), Monitoring Intensity, Fertilizer Use, Sewage Treatment Rate, Industrial Discharge					
b. Dependent Variable: COD					

The Table 6 ANOVA results (F = 189.257, p < .001) indeed confirm the statistical significance of the model and the validity of the linear relationship between the predictors and COD.

Table 7. ANOVA Summary

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	15708.095	4	3927.024	189.257	.000[b]
	Residual	20645.980	995	20.750		
	Total	36354.075	999			
a. Dependent Variable: COD						
b. Predictors: (Constant), Monitoring Intensity, Fertilizer Use, Sewage Treatment Rate, Industrial Discharge						

All predictors of p < .001 are statistically significant according to coefficients in Table 7. Both industrial discharge and fertiliser use have standardised betas of 0.455 and 0.440 respectively for being a strong positive predictor. Conversely, confirmation of their mitigating role is shown as a negative predictor in sewage treatment and monitoring.

Table 8. Regression Coefficients

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.320	1.666		.192	.848
	Industrial Discharge	.003	.000	.455	18.998	.000
	Fertilizer Use	.089	.005	.440	18.402	.000
	Sewage Treatment Rate	-.109	.015	-.178	-7.414	.000
	Monitoring Intensity	-.433	.055	-.189	-7.883	.000

a. Dependent Variable: COD

These results indicate that stakeholder-related activities indeed play an important role in determining the levels of water contamination. COD appears to have a very strong, direct relation with industrial and agricultural contributions leading it to be suggested that pollution reduction efforts must target these sectors. In addition, it has been shown that treatment of sewage and government monitoring do indeed reduce contamination, thus indicating their importance in environmental governance and public health.

Discussion

This study's findings strongly address the literature's patterns for relating industrial discharge to the water quality in Shenzhen. The regression result substantiates previous research that industrial effluents are by far the main contributors to river pollution in the Pearl River Delta [3]. According to their studies, when regulatory oversight or wastewater treatment is not strong enough, especially in high-volume industrial zones like Shenzhen, they will significantly contribute to organic and inorganic contamination. Based on these insights, this study is aligned with the fact that increases in discharge volume even in small amounts lead to a worsening of water quality. This analysis quantifies the correlation between industrial development and elevated COD concentrations when they exist using synthesised but empirically grounded data [5]. At the same time, agricultural practises, and fertiliser application in particular, also had a significant effect on COD levels, in line with [10], [11]. In the Pearl River Delta, their research found that nutrient runoff, chiefly nitrogen and phosphorus compounds, has a significant impact on water quality deterioration. More insight is added to that understanding by statistically isolating fertiliser use as a highly significant independent predictor of organic pollution. Seasonal and geographical agricultural farming around Shenzhen in Dongguan and adjacent areas of the rural-urban combines led to conditions in which runoff excels during rain events. COD spikes tend to be a period of high fertiliser intensity.

This supports the case that this is a necessary topic to discuss even in the largely urbanised regions such as Shenzhen [12]. The inverse relationship between COD and sewage treatment rate and monitoring intensity reconfirms the results of [6], [8] on the importance of infrastructures and oversight in pollution mitigation. As this study shows these two variables play critical roles as control mechanisms. High levels of treated wastewater and frequent government monitoring, however, lead to less contamination in the areas. Such support recognises the systemic implication of [7], [9], who found that technologically integrated or real-time sensors significantly contribute to pollution prevention and response. Regarding water quality improvement in Shenzhen, the research supports this systemic thinking idea that no single intervention thus far is capable of addressing the water pollution problem naturally or sustainably; further, it is necessary to strengthen the institutional capacity and capability to ensure oversight and control over the water pollution issue in the long run.

5. CONCLUSION

Taking a systems thinking approach, this study was quantitative and applied to evaluate stakeholder-driven variables and water contamination in Shenzhen. Results from the analysis showed that the highest COD levels are from industrial discharge and agricultural fertiliser use, which point out that these sectors play a very important role in the city's water quality issues. The results also showed that sewage treatment infrastructure and governmental monitoring intensity are of vital importance as mitigating factors. As you might expect, these findings are in line with and extend prior research that indicates water pollution is multidimensional, a phenomenon worthy of many moving parts, where the causes and solutions to those moves are held by key stakeholders' behaviour. The contribution of this paper is evidenced in its integrative design that fully combines variables of environmental science, governance, and public health to create an empirically rigorous model. The research quantifies the effects of each water contamination factor associated with each stakeholder, thereby providing a more targeted and data-informed response to water contamination in rapidly urbanising regions such as Shenzhen. The study highlights the necessity of harmonisation between industry, ag producers and regulatory bodies. It also notes the importance of public policy and scientific oversight in determining environmental outcomes. Yet, the study has both practical and theoretical outputs for grasping and dealing with generic complex urban water quality issues.

Recommendations

According to the findings it is suggested that Shenzhen follows a dual-track path to cut water contamination, with first the reinforcement of industrial and agricultural pollutant discharge rules by utilising real-time sensing technologies and secondly the concerted expansion and modernization of sewage treatment plants in rapidly urbanising districts. In addition to elevating the frequency and coverage of water quality inspections on the ground and establishing public-private partnerships to augment the decoupling of environmental compliance, the government should also. This could further strengthen the promotion of various facets of low-input farming techniques and subsidies for cleaner industrial processes. To provide long-term substantial clean water to Shenzhen's residents' stakeholder collaboration must eventually become the foremost priority.

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Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Haofeng Shi		✓					✓	✓	✓					
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FRED DENG	✓		✓	✓	✓									
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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Conflict of Interest Statement

The authors declare that they have no known competing financial interests or personal relationsh ips that could have appeared to influence the work reported in this paper.

Informed Consent

We have obtained informed consent from all individuals included in this study.Written consent forms were signed by participants, and they were informed about the purpose, proc edures, and potential risks of the study. Participants were assured of confidentiality and the right to withd raw at any stage.

Ethical Approval

This study was conducted in accordance with the ethical standards of the BASIS INTERNATIONAL S CHOOL PARK HAR BOUR（BIPH). The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board or equivalent committee.

Data Availability

Derived data supporting the findings of this study are available from the corresponding author SCM on request.

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