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Advances in Environmental and Engineering Research

Review

A Review of the Effects of Anthropogenic Activities during the Pandemic Lockdown Period Timeline on Water Quality

Aini Hidayati Shahrir [1], Gasim Hayder [1, 2, *]

1. Department of Civil Engineering, College of Engineering, Universiti Tenaga Nasional (UNITEN), 43000 Kajang, Selangor Darul Ehsan, Malaysia; E-Mails: aini.hidayati@gmail.com; gasim@uniten.edu.my
2. Institute of Energy Infrastructure (IEI), Universiti Tenaga Nasional (UNITEN), Kajang 43000, Selangor Darul Ehsan, Malaysia

* **Correspondence:** Gasim Hayder; E-Mail: gasim@uniten.edu.my

Academic Editor: Khalid S. Hashim

Special Issue: Environmental Management

Adv Environ Eng Res
2023, volume 4, issue 1
doi:10.21926/aeer.2301020

Received: October 27, 2022
Accepted: February 02, 2023
Published: February 14, 2023

Abstract

The pandemic has shown its effect on the world regarding health, economy, society, and environment. Whether it is a negative or positive impact, the period of this pandemic has a vast open platform for further studies. This review focused on the impact of the COVID-19 pandemic lockdown on water quality. It is hypothesized that due to the reduced amount of anthropogenic activity due to the global lockdown, the water quality of water resources increased and rejuvenated. This review showed the study period, methods and parameters used by past researchers in this area. The research methods in this review have proven to be reliable in producing coherent results. The data presented showed a dependable indicator for the pollution and water quality standard whether it is based on the country's standard or World Health Organization (WHO). The review focused on 23 articles from China, India, Malaysia, Morocco, Nepal, and Turkey. Findings from this review showed that the trend between the lockdown period and water quality is not rigid and may be affected by how the area is managed throughout the period. Moreover, this review gives definite suggestions for future studies and highlights the need for actions taken by policymakers.

Keywords

Pandemic; lockdown; water quality; anthropogenic

1. Introduction

The viral transmission known as COVID-19 made a turning point in the world to become one of the deadliest pandemics in history. The pandemic did affect not only the health and well-being of people but also the economy, society, and environment worldwide. After the implementation of the global lockdown in mid-2019-2020, it can be seen there are positive and negative impacts of the lack of human activities on the economy, society, and environment. For the water sector, it can be observed significant changes to the environment throughout the lockdown period. This is due to the reduced amount of pollution from anthropogenic activity especially from the industrial sector [1, 2].

Rivers and streams are the major sources of water resources, whether for daily human supply, industrial needs, or irrigation [3]. Water quality plays an important role in whether the water is safe to use for consumption and up to the standards provided by each country. If the water pollution becomes too drastic, it will deprive humans of one of their basic needs and affect their well-being.

As previously stated, the lockdown of the COVID-19 pandemic took place for almost 2 years, and it is a long enough period to bring drastic changes to the economy, society, and environment. Even though this sudden lockdown has caused harm to the economy, the environment continued to improve due to the lack of human intervention known as anthropogenic activity [4]. Thus, the study on the lockdown period gives a beneficial platform for vast research and this review focused on the environmental impact of the period studied by past researchers.

From past literature, it can be hypothesized that the lack of anthropogenic activity caused by the lockdown period increased the water quality of the area studied. It was proven that the anthropogenic influence on water quality is quite clear as the lockdown's impact becomes apparent [5]. The source of anthropogenic influences comes from agricultural practices, discharge of industrial waste to the river [6, 7], and contamination from sewages, residential areas, and landfills [8], resulting in pollution of the water source.

Most researchers focused on the study of pollution in this area as the status of pollution is proven to be an efficient indicator of water quality. What differentiates between their studies are the water quality parameters and study area for each of their research. This study area affects not only human lives but also aquatic life. Most literature studied suspended particulate matter (SPM) [9], total suspended matter (TSM), and chromophoric dissolved organic matter (CDOM), [10]. These are common problems in waterbody surfaces as the suspended particles reduce light penetration and cause eutrophication [9, 11]. This relates to the turbidity of the water, and it is one of the common water quality parameters studied by past literature.

Kour et al. [12] stated that only water and air quality had been studied as the environmental impacts of the lockdown period. The study of the impact of COVID-19 is still considered novel and a promising platform for research. As we are still in this pandemic, many studies can be generated whether it is the study on the cause and effects of this pandemic. Hence, the need for a review of this lockdown period and water quality parameters can be beneficial for future studies on the methods, limitations and recommendations needs.

Several national limitations were enacted immediately after the first COVID-19 case was reported in Turkey in March 2020, and many are still in effect. But in June 2020, several of the implemented limitations, such as travel bans and industry reductions, started to be gradually eased. Although implementing these restrictions and the lockdown hurt many people's lives, economies, and industries, it probably resulted in significant environmental component regeneration [13]. Furthermore, direct discharges of untreated industrial effluents, agricultural runoff, solid waste, and traffic pollutants during the pre-lockdown period impact the lockdown period. Contrarily, it is affected by weathering, disinfestation by-products, municipal wastewater, and the lockdown effect, which causes different industries to operate at a lower capacity after the lockdown.

Theoretical research on economic and environmental pollution in the context of extreme occurrences was demonstrated in a paper by Wang et al. [14]. The COVID-19 outbreak is a severe occurrence and a global public health disaster. In addition to serving as a guide for other nations evaluating the effects of COVID-19 on the environment, the systematic analysis of the relationship between economic growth and environmental pollution during the outbreak can also advance theoretical research on the relationship between economy and pollution from an emergency-economy-environment perspective [14]. However, the current statistics' inter-annual change rate of carbon emissions recorded is 5% higher than the scenario modelling of carbon emission decrease in China and India. In other ways, the pandemic's effect on poor nations' efforts to cut carbon emissions may be overstated [15]. It was discovered from the literature that developed countries are dedicated to researching educational sustainability while underdeveloped countries have paid more attention to economic sustainability throughout the epidemic. According to the cluster analysis, the COVID-19 pandemic has negatively impacted 17 SDGs goals, but it may potentially present chances for another 14 SDGs goals [15].

From this review, researchers and policymakers can address rejuvenation strategies on the water resources so the positive changes in its quality do not stop when the pandemic ends [12]. This review also highlights the importance of monitoring the water resource from time to time to ensure its quality meets the standards and requirements of every country [10].

The water quality trend cannot be generalized into one trend as every site studied is different not just geographical but also in how the country prioritized and managed the site as part of a water resource. Even though the environment seems to replenish during the lockdown period, anthropogenic activities will resume when the lockdown ends, and the environment may start deteriorating again. Thus, this review showed the great importance and significance how studies conducted in this area. By recognizing the specific source of pollution that is heavily impacted by the COVID-19 pandemic, policymakers can construct a framework for implementing countermeasures and future rejuvenation studies. The aim of this review paper includes (1) to analyze the methods used to study the water quality parameters and area studied by past researchers; (2) to study the hypothesis proposed from the literature on the relationship between lockdown period and water quality; and (3) to summarize the outcomes of previous study that might be beneficial for future studies and rejuvenation purposes.

As previously said, this review focused on the environmental impact of lockdown periods through the parameters of the water quality of the studied area. Hence, the results of the studies do not adhere to the number of COVID-19 cases or relate to any impact on the health and well-being of people, the economy, and society.

2. Methodology

Considering any changes or trends in this study, this paper reviewed 23 relevant open-access studies out of 107 initially available works from Elsevier, ScienceDirect, Scopus, and Google Scholar as of 4th October 2021. The searched keywords for this review include “water," “quality," “COVID-19”, “pandemic” and “lockdown” which were used in various combinations.

Figure 1 shows the countries that are studied in this review. This paper will present and discuss the methodology and outcomes of the relationship between the lockdown period and the water quality parameters.

Figure 1 Countries studied in the review.

The 23 articles detailed the relationship between the lockdown period and water quality parameters as shown in Table 1 where four originate from China, 14 from India, 2 from Malaysia, 1 from Morocco, 1 from Nepal and 1 from Turkey. Eight papers were published in 2020, 14 in 2021, and 1 in 2022 (Table 1). The full article of these 24 papers was obtained and reviewed in-depth.

Table 1 Study area origins for review.

Study Area	Country	Source
Haihe River	China	[11]
China*	China	[16]
Yangtze River Basin (Chengdu)	China	[17]
Min River	China	[3]
Sabarmati River (Ahmedabad section)	India	[1]
Yamuna River	India	[18]
Ashtamudi wetland system, Kerala	India	[9]
Hooghly-Matla estuarine complex, West Bengal	India	[18]

Gangetic delta	India	[19]
Himalaya 1. Ganga River & Yamuna River 2. Alaknanda River, Manadakini & Bhagirithiriver 3. Naini Lake & Bheemtaallake, Nainital 4. Gola River, Kosi River, Dhella River, Bhella of Kumanon Region	India	[20]
Klang River, Penang River, Putrajaya Lake	Malaysia	[21]
Tangier	Morocco	[22]
Bagmati river basin	Nepal	[23]
Meriç-Ergene River Basin	Turkey	[24]
Damomar River	India	[25]
Damomar River	India	[26]
Hooghly River (Ganges) Estuary	India	[27]
Thirumanimuthar River	India	[6]
Gomti River Basin (GRB)	India	[7]
Tawi River	India	[12]
Ganges River	India	[10]
Yamuna River	India	[5]
Vembanad Lake	India	[2]
Malaysia*	Malaysia	[8]

Note: *study area involving the whole country.

3. Results & Discussion

3.1 Lockdown Period Studied

The lockdown period studied by past researchers in this review comprised before, pre-, during, and post-lockdown. Table 2 shows the variation of the periods used for each study.

Table 2 Variation of period studied.

Period	Country	Source
Before, pre, during lockdown	India	[1]
Before, pre, during lockdown	India	[9]
Pre, during lockdown	India	[18]
Pre, during lockdown	India	[20]
Pre, during lockdown	India	[25]

Pre, during lockdown	India	[26]
Pre, during lockdown	India	[19]
Pre, during lockdown	India	[12]
Pre, during lockdown	India	[10]
Pre, during lockdown	India	[5]
Pre, during lockdown	India	[2]
Pre, during lockdown	Turkey	[24]
Before, during lockdown	China	[17]
Before, during lockdown	India	[27]
Before, during lockdown	India	[6]
Before, during lockdown	Malaysia	[8]
During lockdown	China	[11]
During lockdown	Morocco	[22]
Pre, during , post	India	[7]
Before, during, post	China	[16]
Before, post lockdown	Malaysia	[21]
Pre, during lockdown	Nepal	[23]
Before, pre, during , post lockdown	China	[3]

As illustrated in Figure 2, the variation of periods contributes as one of the major factors in analyzing the trends between the period which is the main point for this review.

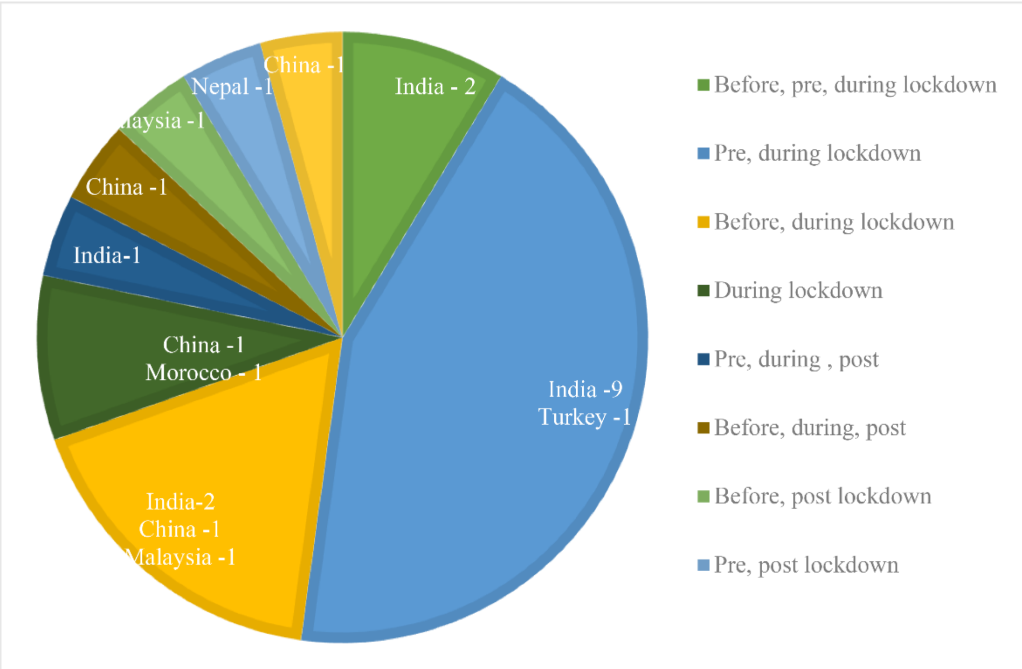

Figure 2 Variation of period studied.

Moreover, studying the lockdown period can analyze the changes and impacts that occurred during the lockdown enforced by the pandemic. In addition, the lockdown period is not fixed but varies in different countries. Table 3 highlights the lockdown period of each country involved in this review. From the table, the lockdown period ranges from 18-441 days.

Table 3 Variation of Lockdown Periods in Different Countries.

Before lockdown period	< February 2020			
Pre-lockdown period	February 2020-March 2020			
Lockdown period	Country	Start	Ends	Days
	China	23/01/2020	08/04/2021	441
	India	25/03/2020	07/06/2020	74
	Malaysia	18/03/2020	16/08/2021	187
	Morocco	19/03/2020	10/06/2020	42
	Nepal	24/03/2020	09/09/2020	141
	Turkey	29/04/2021	17/05/2021	18
Post-lockdown period	Country	Start		
	China	> 08/04/2021		
	India	> 07/06/2020		
	Malaysia	> 16/08/2021		
	Morocco	> 10/06/2020		
	Nepal	> 09/09/2020		
	Turkey	> 17/05/2021		

One of the key differences between the periods is the number of days in the period. Turkey only experienced 18 days nationally of lockdown, Morocco 42 days, India 74 days, Nepal 141 days, Malaysia 187 days and China 441 days. The lockdown period increase based on the country's management of COVID-19 crisis. Like all viruses, the COVID-19 virus changes over time, leading to an overwhelming increase in cases that are harder to combat. For countries which is the origin of the virus, or developing countries, the crisis is worse compared to other which resulted in a higher lockdown period enforced by their government.

One tactor that affects the period selection is the length of the period. As discussed previously, the period of lockdown varies with the enforcement of government in combating the COVID-19 crisis. Another possible factor contributing to the period's selection is the accessibility of water quality parameters data. The common variation of periods studied is either before and during the lockdown, or pre-and during the lockdown. From the period differences, an analysis can be made from the parameters evaluated. There is a trend for researchers in India to study the pre and during-lockdown period (9 studies).

Nevertheless, it cannot be said that one period variation is better than the other because every research focused on analyzing the data comprehended by each period. Studying before or during the lockdown period is a common choice for research due to the availability of the data. However, three articles studied the post-lockdown period in their variations [4, 7, 16]. The matter of obtaining the post-lockdown period cannot simply be handed. Rather than needs to be forecasted or predicted. The methods used for the analysis conducted by these studies will be discussed in the next subtopic.

3.2 Methods Used

This review highlights six methods used by past researchers: third-party data; statistics analysis; index calculations; model development; sampling and water quality analysis; and remote sensing using satellite images.

Methods like third-party data are often used to maintain coherence in comparative assessment [6]. Third party data is collected from various platforms for research and study, these data usually come from government organizationsor or non-government organizationsors. In times of the pandemic lockdown, retrieving samples can be harder to acquire and historical data is the most reliable for its accuracy and integrity.

In most cases, water sampling can be reliable as it takes a portion of water from the sample site and undergoes relevant water quality testing. However, in the case of a pandemic lockdown, studies that used this method focused on a site where it is a river basin [12, 17, 23, 24] or stream that already has constant water monitoring hence, the retrieval of sample results is proven reliable.

Next, the remote sensing method using satellite images is often used when field data collection or sampling is not feasible during lockdown [7, 10]. Remote sensing is known to be effective in calculating the turbidity of water as it detects spectral signatures of various suspended solids [4]. Satellite images have proven another reliable method as it tracks the changes in human footprint across the globe using satellites, i.e., Landsat-5, and Landsat-8.

Besides that, statistical analysis is used when there is a set of data with many variations [23]. Statistical analysis often uses software to ensure the accuracy of the data. For instant, PAST software version 4.03 and MS Excel are common software for statistics [12]. The statistical approach can ensure the raw data or dataset retrieved from sampling, third-party data or satellite images be processed for further and thorough analysis to create a reliable outcome for the study.

Furthermore, models are derived, and tested to fit the desired outcome. Machine learning algorithms are utilized to predict accurate water quality parameters for model development in water quality analysis during the lockdown period. This type of model i.e., Multi-layer Perceptron (MLP) has proven points of accuracy more than other models in forecasting indexes in different periods [21]. Models are reliable when it comes to comprehensive study for a specific parameter, i.e., chemical parameters were determined by ESICO MODEL 1382 [23].

Lastly, index calculations used the weighted arithmetic index method with the specific equation [7] for specific index i.e., Water Quality Index (WQI), Water Pollution Index (WPI), Trophic State Index (TSI), Heavy Metal Pollution Index (HPI) and Metal Index (MI). Index calculation serves as a good indicator for trend analysis and forecast purposes. The fundamentals of index calculation in water quality parameters are that it ranges through all its parameters including biological, physical, and chemical and distills environmental data to indicate the health and pollutants in water resources upon access. Thus, Figure 3 shows the six methods used by researchers analyzed in this review.

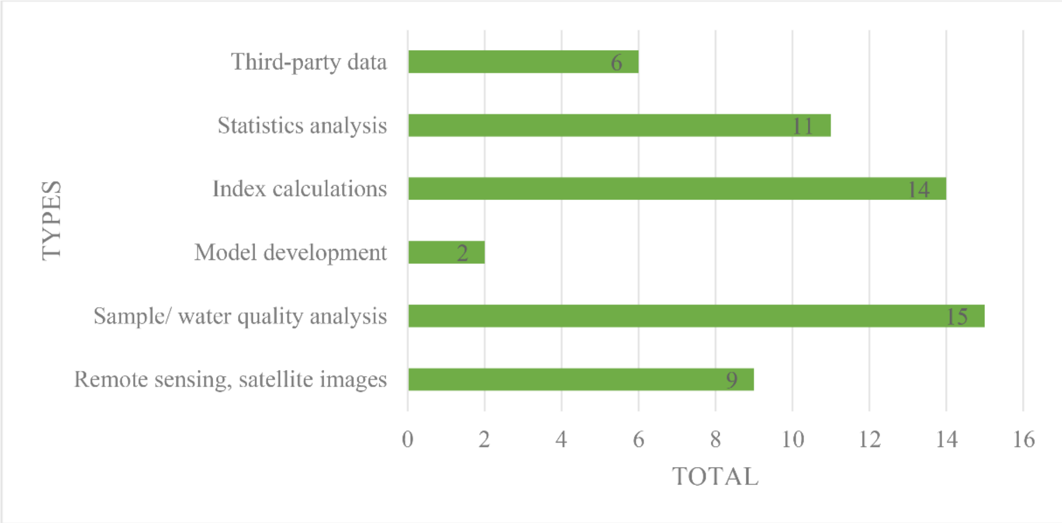

Figure 3 Number of methods used by researchers.

A thorough explanation of the methods for each study is shown in Table 4. The most popular methods used by these researchers are sampling and water quality analysis, followed by index calculation, statistics analysis, remote sensing through satellite images, using third-part data, and model development.

Table 4 Methods used by researchers.

Source	Country	Method
[1]	India	1. Landsat 8 Surface Reflectance 2. Suspended particulate matter (SPM)
[18]	India	1. Data collection from Central Pollution Control Board (CPCB) 2. Water quality monitoring
[9]	India	1. Landsat 8 Surface Reflectance image. 2. Suspended particulate matter (SPM)
[20]	India	Data collected from past research
[25]	India	1. Sample collection & analysis 2. Water Quality Index (WQI) 3. Trophic State Index (TSI) 4. Statistical analysis
[26]	India	1. Sample collection & analysis 2. Water Pollution Index (WPI)
[27]	India	1. Sample collection & analysis 2. Statistical analysis
[19]	India	1. Random sampling 2.Statistical model; Sigma Plot 11.0
[11]	China	1. Data & pre-processing using Sentinel-2A & Sentinel-2B

		2. Water extraction & Normalized Difference Water Index (NDWI) 3. Statistics of lighting data
[22]	Morocco	1. Analysis using Sentinel 3 images 2. Water Surface Temperature (WST) data using MATLAB 3. Coastal Water Quality Estimation using E.coli data
[6]	India	1. Sample collection 2. Statistical analysis 3. Heavy Pollution Index (HPI) 4. Metal Index (MI) 5. Hazard Index (HI)
[7]	India	1. Data collection from Uttar Pradesh Central Pollution Control Board 2. Water Quality Index (WQI)
[12]	India	Statistical analysis.
[8]	Malaysia	Data collection from Department of Environment (DOE)
[16]	China	1. Third party data collection 2. Water Quality Index (WQI) 3. Statistical analyses
[10]	India	1. Sentinel 2-multi-spectral instrument (MSI) 2. TSM, Chl-a, CDOM model, Total Suspended Matter (TSM), Chlorophyll-a concentration (chl-a), CDOM Adsorption Coefficient
[21]	Malaysia	1. Water quality data 2. Model development 3. Water Quality Index (WQI)
[23]	Nepal	1. Sampling design & chemical analysis 2. Statistical analysis 3. Water Quality Index (WQI) & Irrigation Water Quality Index (IWQI)
[5]	India	1. Water quality data source from Delhi Pollution Control Committee (DPCC) 2. Water Quality Index (WQI)
[17]	China	1. Water monitoring system 2. Water quality measurements & evaluation 3. Water Quality Index (WQI) & Chinese National Method to Evaluate Surface Water Quality (CNWQS)
[24]	Turkey	1. Sampling & analysis 2. Metal pollution indices (Heavy metal pollution index HPI, Heavy metal evaluation index HEI) 3. Human health risk assessment 4. Statistical analyses

[3]	China	1. Remote sensing data, satellite images 2. Algorithm 3. Evaluation metrics; mean absolute
[2]	India	1. Landsat-8 OLI images 2. Suspended particulate matter (SPM) algorithm

The two most popular methods are based on the availability to perform sampling analysis and on the accuracy and integrity of the data. As said previously, index calculation is a good indicator and outcome for the result analysis as it gives a definite value that can be categorized in a specific level standardized by a previous study, country, or even global standards i.e., World Health Organization (WHO) drinking water standards.

3.3 Water Quality Parameters Used

The average number of water quality parameters studied before, pre-, during, and post-lockdown is 31, 38, 40 and 19 respectively. The period with the highest value of water quality parameters is during the lockdown followed by pre-, before and post-lockdown as shown in Figure 4.

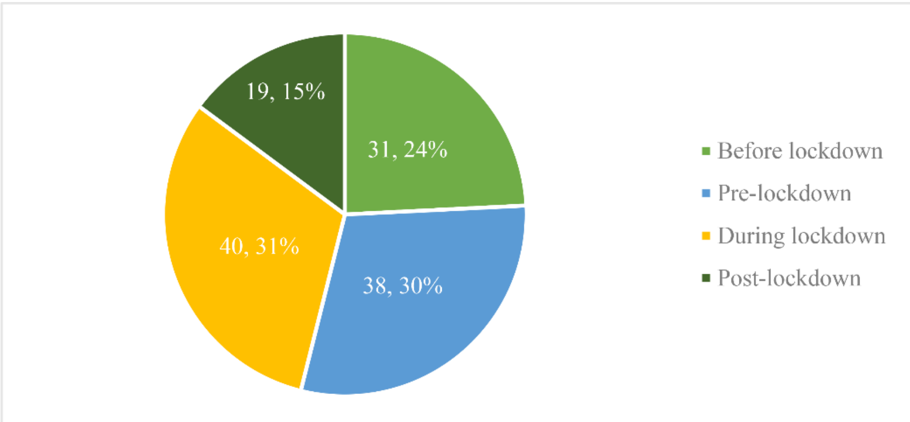

Figure 4 Percentage of Water Quality Parameters studied in each period.

The common parameters used are alkalinity, ammonia, bicarbonate, BOD, cadmium, calcium, chloride, chlorine, chromium, COD, conductivity, DO, fecal coliform, hardness, lead, magnesium, nitrate, pH, phosphate, potassium, sodium, sulfate, TDS, temperature, total coliform, turbidity, and zinc. The analysis of these parameters as each parameter has its effects on the environment. Thus, the existence of standardized water quality to ensure the water source does not exceed it that may lead to negative impacts on the environment.

Higher alkalinity on water bodies resists acidity to resurface at the atmosphere which may lead to acid rain. In contrast, the higher amount of ammonia indicates direct toxic effects on aquatic life that cause over-enrichment of nutrients to the water bodies. This relates closely with pH measurement as pH indicates whether the water is acidic or basic. As temperature increases, excess amounts of bicarbonate and calcium may lead to scale formation.

As bacteria needs dissolved oxygen (DO) to break down organic matter, an increased amount of organic matter leads to a lower amount of DO. Meanwhile High Biological Oxygen Demand (BOD) readings showed too much organic matter. This also happened to Chemical Oxygen Demand (COD) towards organic matter, indicating a high level of plan decay or waste. Higher level of Total Dissolved Solids (TDS) do not lead to health hazards but alter the water's taste.

Chemicals in water can only be found in low volume; however, when they exceed the standards, health hazards can occur. The hardness of water from calcium and magnesium in the water content does not indicate a health hazard. Higher levels of lead can cause a chemical reaction called corrosion when entering drinking water. Potassium can be found in drinking water but it is generally low. However, the high solubility of potassium chloride can lead to increased exposure.

On the other hand, the existence of fecal coliform indicates water is contaminated with fecal matter from beings and this leads to waterborne pathogenic diseases. This goes with high total coliform; it indicates the need for sanitary condition of water supply.

Chloride increased electrical conductivity and increased its corrosivity. Even though chloride is not harmful to drink water standards, it relates to sodium. Higher levels of chloride and sodium are indicators of water pollution. Besides, chlorine helps remove iron and manganese and is a potent germicide. If chlorine exceeds its standards, it leads to disease-causing microorganisms in drinking water.

When cadmium in water is raised to a higher level, this cadmium exposure can be a long-term negative impact above the maximum contaminant level. Chromium is highly toxic to flora and fauna, higher chromium levels will destroy aquatic plants.

Next, nitrate and phosphate in excess amounts, can accelerate eutrophication which causes significant water quality problems. Similarly, turbidity relates to the clarity of water. It affects the growth rate of algae when it increases and causes reduced light penetration of the water bodies for photosynthesis, which lead to eutrophication. When combined with calcium and magnesium, higher sulfate concentration can lead to a laxative effect in drinking water. Excess zinc can also lead to health issues when water is drunk, which leads to nausea, vomiting and cramps.

3.4 Lockdown Period and Water Quality Parameter Trends

There are a variety of trends between the lockdown period and water quality parameters. Pre and during the lockdown, alkalinity dropped to roughly 88.32 mg/l. The results for ammonia decreased by 7.25 mg/l from before to during the lockdown and remained steady afterward. The ammoniacal nitrogen concentration dropped by 0.11 mg/l. From before to after the lockdown, the arsenic level dropped by 0.002 mg/l.

Bicarbonate levels dropped to roughly 25.78 mg/l before and during the lockdown, then dropped to 289.09 mg/l during the lockdown and stayed constant afterward. Meanwhile, BOD drops 60.7 mg/l, 17.68 mg/l, and 90.34 mg/l before, during, and after lockdown, and rises 60.7 mg/l, 17.68 mg/l, and 90.34 mg/l post-lockdown, respectively.

Cadmium levels rise by 8.10 mg/l before the lockdown and fall by 7.10 mg/l during the lockdown. Calcium's volume increased by 80.54 mg/l before the lockout and decreased by 66.28 mg/l and 28.82 mg/l during and after the lockdown, respectively. This pattern is comparable to chloride, with pre-, during, and post-lockdown concentrations of 333.59 mg/l, 209.09 mg/l, and 147.97 mg/l, respectively. Chlorine levels dropped 46.91 mg/l from before to after the lockdown. Pre- and during the lockdown, chromium levels increased by 0.07 mg/l and decreased by 0.14 mg/l.

COD levels dropped by 384.2 mg/l and 65.95 mg/l before and during the lockdown, respectively, before rising by 197.91 mg/l afterward. Before and during the lockdown, conductivity increased by 1.14 mg/l and reduced by 0.63 mg/l, respectively. DO increase by 7.39 mg/l before the lockdown and decreased by 3.90 mg/l, 3.18 mg/l during and after the lockdown.

During and after the lockout, electricity conductivity increased by 199.35 µS/cm and decreased by 363.56 µS/cm, respectively. The amount of Escherichia coli in the blood dropped by 29 MPN/l/l from before to after the lockdown. Fecal coliform increased by 1898.59 MPN/l/l from before to during lockdown, bucking the norm. During the lockout, fluoride levels dropped by 1.25 mg/l.

Pre- and during the lockdown period, iron levels declined by 2.58 mg/L and increased by 1.19 mg/L. Lead levels rose to 13.07 mg/l before the lockout and then fell to 13.09 mg/l during the lockdown. Magnesium levels began to rise before the lockout and then fell by 54.82 mg/l, 43.36 mg/l, and 13.75 mg/l, respectively, during and after the lockdown. For pre-and during the lockdown, manganese decreased by 0.046 mg/l and increased by 0.002 mg/l, respectively. Nickel levels dropped by 0.004 mg/l and 0.008 mg/l during the pre-and post-lockdown periods.

Nitrate levels rose to 75.05 mg/l before dropping to 54.02 mg/l and 21.31 mg/l before, during, and after the lockdown. By the end of the period, the pH levels had dropped by 0.46 mg/l, 0.46 mg/l, and 0.21 mg/l, respectively. Throughout the period, phosphorus declined by 1.48 mg/l and increased by 0.157 mg/l and 1.39 mg/l. During the pre-, during, and post-lockdown periods, potassium levels increased by 264.32 mg/l, then declined by 196.73 mg/l and 69.43 mg/l, respectively.

Sodium increased by 455.57 mg/l and then decreased by 404.91 mg/l and 57.70 mg/l, whereas sulfate decreased by 1.16 mg/l and 2.31 mg/l before increasing by 2.62 mg/l, following the previous trend. TDS increased by 260.4 mg/l before decreasing by 340.83 mg/l, 172.82 mg/l, and 340.83 mg/l after the lockout, respectively. From before to after the lockdown, the temperature increased by 9.08 °C, while total coliform increased by 3443.09 MPN/l/l.

Pre-lockdown, total hardness increased by 125.68 mg/l, then dropped by 91.21 mg/l and 34.47 mg/l during and after lockdown, respectively. During the pandemic lockdown, the TSI and TSS decreased by 10.17 and 7.5 mg/l, respectively. Throughout the interval, turbidity increased by 18.41 mg/l, reduced by 0.40 mg/l, and then increased by 31.78 mg/l.

During the pandemic lockdown, the WPI and WQI declined by 1.41 and 142.84 points, respectively, whereas zinc increased by 1.91 mg/l before the lockdown and decreased by 1.20 mg/l during the lockdown.

There are eight types of lockdown periods and water quality parameter trends as shown in Figure 5. Throughout the period, the two most typical trends are 'decrease' and 'increase-decrease-decrease.'

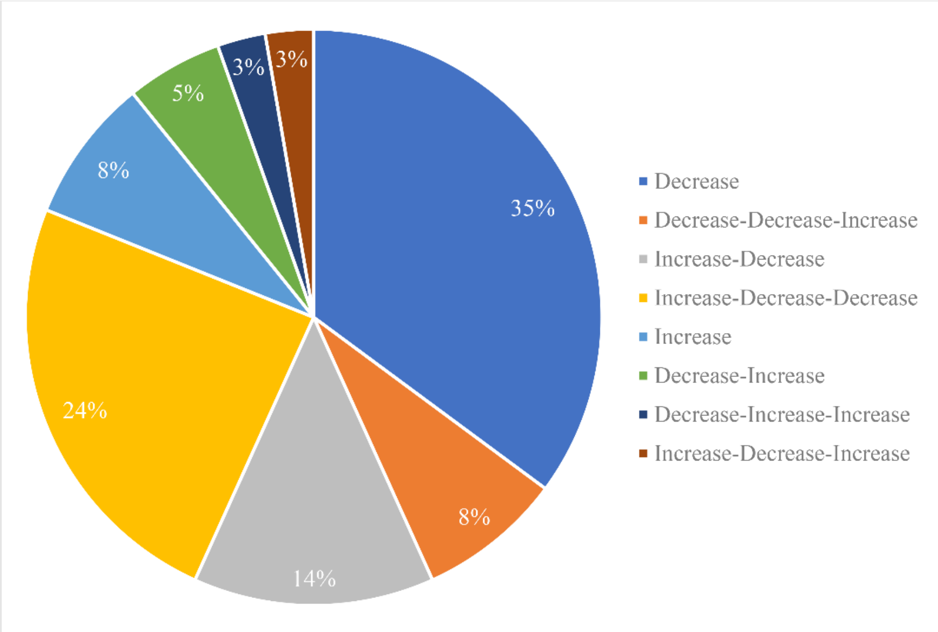

Figure 5 Variations of Trends of Water Quality Parameters Throughout The Period.

Next, Figure 6 depicts a comparison of the water quality characteristics investigated during each period.

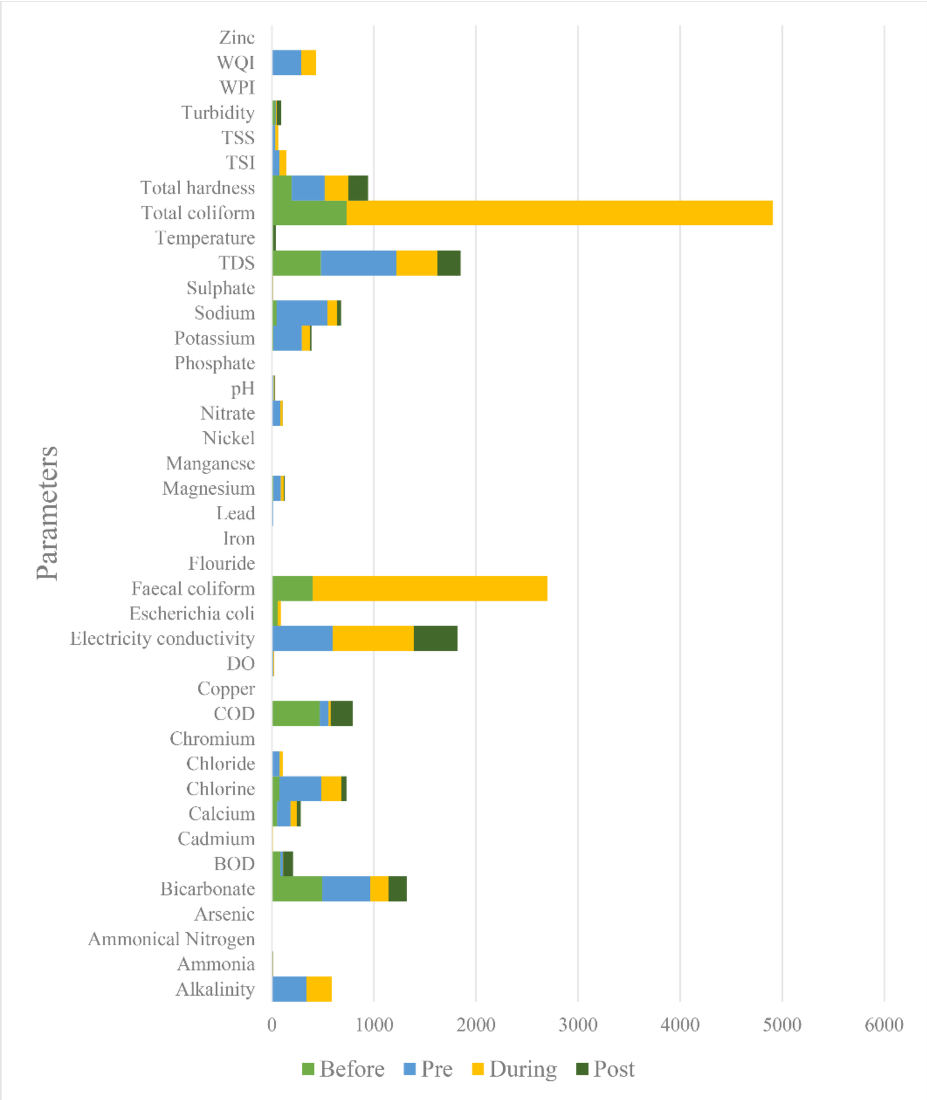

Figure 6 Comparison of Water Quality Parameters Studied in Each Period.

A table of data recorded for each study are shown in Table 5.

Table 5 Data Recorded for Each Study.

		Before					Pre							During								Post
Parameters	Unit	[1]	[9]	[27]	[6]	[23]	[1]	[18]	[9]	[25]	[26]	[12]	[24]	[1]	[18]	[9]	[25]	[26]	[27]	[27]	[21]	[24]	[23]
Alkalinity	mg/l									467.270		208.000					313.640			185.000			
Ammonia	mg/l					7.290															0.040		0.040
Ammoniacal Nitrogen	mg/l			1.070															0.960				
Arsenic	mg/l												0.00351									0.00140	
Bicarbonate	mg/l					493.970				468.180							179.090						179.090
BOD	mg/l			3.670		162.800		66.580		12.550		2.780	8.230				7.270		1.680	2.130	4.000	9.220	95.200
Cadmium	mg/l			0.00200	0.00200						16.20000		0.00005					2.00000				0.00002	
Calcium	mg/l					50.550				131.090	131.090						64.820	64.810					36.000
Chlorine	mg/l					73.680				407.270	407.270						198.180	198.180					50.210
Chloride	mg/l									76.09							29.18						
Chromium	mg/l			0.06300									0.13760									0.00083	
COD	mg/l					469.840		211.600				12.500	32.820							10.750	14.000	34.330	217.600

Copper	mg/l	0.0216	0.0490				2.3436		0.0043			1.091				0.0007	
DO	mg/l	4.2		1.6	17.0	4.9			8.9	3.9	7.3		6.2		7.8	6.7	3.2
Electricity conductivity	µS/cm				152.6	115.7	1157.2	308.0	1242.4		820.1	820.1		268.0		1270.0	431.0
Escherichia coli	MPN/l/l		58.000										29.000				
Faecal coliform	MPN/l/l	682.233	120.000										2299.710				
Flouride	mg/l						1.960					0.710					
Iron	mg/l	0.532	0.480			4.550	1.619				3.590	0.207					
Lead	mg/l	0.02800	0.00600				26.180		0.00051							0.00015	
Magnesium	mg/l			15.540		70.360	70.360				27.000	27.000					13.250
Manganese	mg/l		0.072						0.026							0.028	
Nickel	mg/l		0.01300						0.00906							0.00097	
Nitrate	mg/l	1.550		3.760		68.950	86.450				34.650	35.180	1.210				2.370
pH	mg/l	7.440		9.560	7.600	7.460	7.450	8.730	8.960	7.300	6.920	6.920	7.510	8.510	7.590	8.320	7.370
Phosphate	mg/l	0.830		2.260		0.062					0.018		0.420				1.610
Potassium	mg/l			13.86			278.18					81.45					12.02

Sodium	mg/l					44.430					500.000							95.090					37.390
Sulphate	mg/l					4.740				3.582	3.582						1.273	1.273					3.890
TDS	mg/l			397.500		563.000				740.650	740.650						524.860	524.850	149.750				227.000
Temperature	°C					15.500																	24.580
Total coliform	MPN/l/l			1259.900	207.000														4176.540				
Total hardness	mg/l					195.28				470.91		171.00					282.00			177.50			195.28
TSI										74.940							64.770						
TSS	mg/l												34.080								4.000	49.160	
Turbidity	mg/l	9.710	12.020			63.737	12.720		10.030				7.487	8.080		8.010						12.963	41.460
WPI											2.070							0.660					
WQI										286.700							195.520				92.200		
Zinc	mg/l			0.0902	0.0820						3.9845		0.0082					1.5936				0.0013	

4. Conclusion

To summarize, studying the before, during, and post- ; or pre-, during, and post ; or before, pre-, during, and post-lockdown can be said to be more comprehensive compared to others when it comes to concluding the impacts of COVID-19 towards the water quality parameters and the lockdown periods.

What can be concluded from the methods used, most researchers used reliable methods to produce coherent results. The integrity and accuracy of the data rely solely on how efficient the study's methodology is. The procedure, limitations and expected outcomes for a specific study must be laid out firsthand in the methodology before proceeding with the data collection. This is important as water samples can be easily contaminated if not handled properly; hence, the results from laboratory testing will not help me be efficient and accurate.

Every parameter has its role in water quality analysis. The common parameters that researchers in this review use are alkalinity, ammonia, bicarbonate, BOD, cadmium, calcium, chloride, chlorine, chromium, COD, conductivity, DO, faecal coliform, hardness, lead, magnesium, nitrate, pH, phosphate, potassium, sodium, sulphate, TDS, temperature, total coliform, turbidity, and zinc.

The two most common trends are 'decrease' and 'increase-decrease-decrease' throughout the period. This is susceptible to the hypothesis made by researchers as going into the pandemic lockdown; the water quality is flourishing as the pollution decrease based on the results of water quality parameters.

The water quality trend cannot be generalized into one trend as every site studied is different not just geographical but also in how the country prioritized and managed the site as part of a water resource. This review can conclude even though the environment seems to replenish during the lockdown period. However, anthropogenic activities will resume when the lockdown ends, and environment may start deteriorating again. Thus, this review showed the great importance and significance how studies conducted in this area. By recognizing the specific source of pollution that is heavily impacted by the COVID-19 pandemic, policymakers can construct a framework for implementing countermeasures and future rejuvenation studies.

This review is also beneficial for future studies as it gives a review of past methods by past researcher and encourage future studies to test different methods, sites, parameters, and period study. This review highlights that data collection, evaluation and analysis can be further improved for a more coherent result. The findings of this review also draw further attention to the need to forecast future data on water quality to enable proactive countermeasures. Besides that, implementing United Nations (UN) Sustainable Development Goals (SDG) may improve and center rejuvenation strategies after the pandemic.

Acknowledgments

This research was funded by the Universiti Tenaga Nasional (UNITEN) BOLD Fund.

Author Contributions

A.H.S collected and analyzed the results, G.H. writing, review, and editing. All authors reviewed the manuscript.

Competing Interests

The authors have declared that no competing interests exist.

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