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Relationship between Urban Growth and Water Pollution: Experience of Kano Metropolis, Nigeria

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Abstract: Rapid urban and population growth in the Kano metropolis is causing a total distortion of the natural environment and affecting the environmental quality for human habitation. This study evaluates the extent of water pollution to urban growth environmental impacts in the Kano metropolis. Water pollution samples were taken from existing historic ponds in the metropolis. Two ponds were selected: Haura Wanki with coordinates 11.98319500 and 08.50883333 located along Bayero University Road and Shema Pods with coordinates 12.00631333 and 08.50623333 located in Dala local government along Wudil Road. Selection is based on their location. The sample water was analyzed in the laboratory for physicochemical elements. COD, color, t-hardness, salinity, suspended solid, nitrate, nitrite, iron, cobalt, copper, manganese, and nickel were considered in the study. Water quality results reveal suspended solid contents and the salinity level of the Shema Ponds as (248 mg/l and 25 mg/l) and Hauran Wanka Pond with (61 mg/l and 20 mg/l) but Color and t-hardness Hauran Wanka Ponds indicate (501 ml/g and 0.16 mg/l) and Shema Pond with (290 mg/l and 0 mg/l). The water pollution demonstrates that both Ponds are highly polluted because of residents' solid waste dumping in them, sewer discharge in them, and other pollutants discharged in them. This calls for proactive and effective urban management water pollution guidelines to be developed for the metropolis, which could also be used in Africa and developing nations globally.

Keywords: urban growth, water pollution, Kano metropolis, ponds.

城市增长与水污染的关系：尼日利亚卡诺大都市的经验

摘要：卡诺大都市快速的城市和人口增长造成了自然环境的全面扭曲，影响了人类居住的环境质量。本研究评估了水污染对卡诺大都市城市增长环境影响的程度。水污染样本取自大都市现有的历史池塘。选择了两个池塘：位于巴耶罗大学路沿线的坐标为 11.98319500 和 08.50883333 的小时步行和位于伍迪尔路沿线达拉地方政府的坐标为 12.00631333 和 08.50623333 的架构吊舱。选择基于它们的位置。在实验室对样品水进行理化元素分析。研究中考虑了化学需氧量，颜色，t 硬度，盐度，悬浮固体，硝酸盐，亚硝酸盐，铁，钴，铜，

锰和镍。水质结果显示，沙马塘的悬浮固体含量和盐度水平为（248 毫克/升和 25 毫克/升）和豪兰万卡塘（61 毫克/升和 20 毫克/升),但豪兰万卡塘的颜色和 t 硬度为（501 毫升/克和 0.16 毫克/升）和沙马塘（290 毫克/升和 0 毫克/升）。水污染表明，由于居民的固体废物倾倒在其中，下水道排放在其中，以及其中排放的其他污染物，这两个池塘都受到高度污染。这就要求为大都市制定积极有效的城市管理水污染指南，这也可以在非洲和全球发展中国家使用.

关键词：城市增长、水污染、卡诺大都市、池塘.

1. Introduction

Water pollution is also an essential variable of rapid urban growth and expansion. This occurs through sewer discharge, industrial effluent, and solid waste from industrial and household discharge. Contributors to these aspects include water pollution, as discussed by Melian [1], who mentioned that the discharge of polluted and untreated wastewater in urban areas causes great environmental degradation from wastewater of urban areas, the agricultural sector, and industrial activities. Pollutants consist of both biodegradable and non-biodegradable organic matter such as heavy metals, turbidity, suspended solids, nutrients, pesticides, and pathogens that are highly harmful to human health. Liu et al. [2] discovered that stormwater from a highway in cities is the major medium through which microplastic is conveyed to an aquatic environment from its sources. Animals and aquatic ecosystems face challenges from contaminants such as endocrine-disrupting compounds (EDC), traced organic contaminants (TrOCs), and pharmaceuticals. Discharge of treated sewage is the major (TrOCs) to the aquatic environment [3]. Rajasulochana and Preethy [4] revealed heavy metal discharge to water bodies from cities, which are not biodegradable. Awasthi et al. [5] evaluated dewatered fresh sewage sludge (DFSS) as an innovative amendment. Rosa et al. [6] focused on three major areas, which are (a) the survival and persistence of COV in water, (b) the water environment, and (c) COV in water methods of its recovery. Hu et al. [7] discussed water pollution in urban areas, including a study that handles processes integrated with an emphasis on a combination of ozonation, ceramic membrane filtration, and biological activated filtration (Oz + CMF+ BAC processes). The three stages involved in the study are (a) feed water, (b) pilot study, and (c) analysis. Hu et al. [7] mentioned that the parameters involved in the study include PH, color, connectivity, COD, BOD, TDS, NH_4, and Po_4. Valitalo et al. [8] studied wastewater treatment plants (WWTP), which are the primary sources of estrogenic compounds, particularly in the aquatic environment. Two in vitro tests were conducted, namely (a) biotests and (b) chemical analysis. These methods are essential for screening and monitoring.

1.1. Water Pollution in Urban Areas

Gain et al. [9] revealed that water is the most integral commodity essential for humans and plays a key role in society through equity, stability, and productive societies and ecosystems. This is the goal of the 16th United Nations, which focuses on ensuring water security. Water pollution is the direct and indirect introduction of unwanted substances or pollutants into existing water bodies. It is a global challenge where pollutants are viewed under two categories, point sources and non-point sources [10]. Water pollution occurs whenever undesired substances are induced or put into water, which is seen as water pollution. Alteration in the biological or chemical composition of water bodies has diverse and adverse negative consequences on aquatic life as well as the consumers of water [11]. There is a strong need to determine the ranges and conditions of sewers concerning water pollution and to objectively compare the results [12].

1.2. Sources of Water Pollution

Ogbojige et al. [13] employed indicators such as turbidity, temperature, total dissolved solids (TDS), chloride ions (Cl), electrical conductivity (EC), dissolved oxygen (DO), biochemical demand (BOD), and chemical oxygen demand (COD) among others. Residential and agricultural pollutants, together with industrial waste, drain directly to the Thomas Dam in the Kano metropolis [14]. Salihu et al. [15] mentioned that in Nigeria, there are two main pollution sources: (a) point sources that have direct contact with water bodies, mostly from industrial waste, and (b) non-point sources, which pose difficulties in tracing the exact origin. Rashid et al. [16] indicated that outsourced water pollution includes domestic waste, industrial waste, agricultural waste, population growth, leakages from reservoirs, radioactive waste, and weak management. Waterborne diseases include typhoid, cholera, hepatitis, and poliomyelitis, among others [16]. Qin et al. [17] argued that pollutant load generation is directly linked with socioeconomic development. This occurs through industrial waste discharge and related commercial activities. Ouyang et al. [18] showed that remote sensing technology is currently used to control and monitor water quality. Classification of the degree of pollution by the research is relatively clean, lightly polluted, moderately polluted, seriously polluted, and extremely polluted. Patrie et al. [19] commented that EC (emerging contaminant) includes (a) human metabolism, (b) microbial transformation, and (c) physio-chemical processes.

1.3. Urban Growth and Water Pollution

Batu et al. [11] explained that water quality is distorted in urban areas and is therefore affected by numerous challenging factors such as population growth, climate change, pollution, water consumption, and pressure on water resources. Liyanage and Yamada [20] depicted the water quality concerning human activities within the selected sites. It also considered three stages of urbanization regarding water shade population density. The population density of water shade significantly affects water quality. The higher the population, the lower the quality, whereas the lower the population, the better the quality.

Wang and Kalin [21] revealed that urban fractions are directly compatible with the population but reduce cropland fractions. The study shows that future monthly climate change flow and land use land change are statistically significant when the changes scenario is combined, resulting in more monthly average flow, and there is no linear correlation between climate change and land use land change. Land use, land-use change, and climate change together pose a negative impact on the natural environment. Qin et al. [17] depicted that rapid urbanization is seriously changing surface water quality and posing serious predicaments. The study revealed that at the early stage of urbanization in the study area, water quality was highly affected. However, the water quality has improved in recent years.

Gliska–Lewczuk et al. [22] mentioned that rivers serve as connectors between sea and watersheds and therefore transport pollutants from their initial sources. Pollutants are the products of human activities that consequentially affect water quality. Ouyang et al. [18] showed that rapid urbanization in China since 1978 is posing significant environmental impacts, specifically on water. The land sat images of 2000 were the basis of the river pollution level evaluation employed in the study. The results reveal higher and more obvious pollution within the development processes in urban areas. Urbanization activities and processes negatively affect urban water quality. Lifestyle changes in China promote dramatic urbanization. This brought a lot of concern to geographers in China. Urbanization's environmental effect is obvious daily. These generate strong interest in the minds of researchers, especially in water bodies [18].

Wang and Kalin [21] revealed future potential changes in flow with relation to the total suspended solids (TSS) together with nutrients specifically to nitrogen and phosphorous loading to climate change as well as land use land cover changes scenario. This study employed a soil and water assessment tool (SWAT). SWAT effectively simulates water quality processes in the hydrological cycle. Li et al. [23] argued that an increase in human activities that affect and change urban rivers causes extinction along with great losses of species of biodiversity. Luo et al. [24] discovered that water quality in China is being reduced due to rapid urbanization processes. This episode leads to a great threat to the aquatic life, looking at the entire system. The study area land-use changes are categorized into (a) farmland, (b) unused land, (c) forestland, (d) grassland, (e) urban land, and (f) water bodies. The study reveals serious negative consequences of urbanization on macroinvertebrates community compositions. Urbanization, therefore, affects both compositions and distributions [24]. Qin et al. [17] observed sustainable development could be achieved simultaneously with urbanization if only these factors are considered, namely (a) time waste-water infrastructural development, (b) effective management, (c) environmentally conscious campaign and awareness, and (d) effective coordination by planners.

1.3.1. Water Pollution Indicators

The World Health Organization (WHO), as cited in Rashid et al. [16] indicate that water pollution in urban areas is the major cause of 70% of diseases directly related to water pollution. Okpoli [25] indicates the physiochemical indicators in the collected samples for the study, which include PH value, temperature, and turbidity. T. Ds, CODs, and EC. Okpoli [25] spelt the following as the physiochemical indicators in the collected samples for the study, PH value, temperature, turbidity, total dissolved solids (T. Ds), chemical oxygen demand (CODs), and EC. Water on the surface of the earth covers 70% of the total water, and it is among the basic ingredients for human life and survival. Besides, WHO pointed out that 80% of diseases are directly connected to waterborne [16]. Hoekstra et al. [26] focused on four major parts of water security which include (a) equity, (b) sustainability, (c) welfare, and (d) water risk-related. Water security indicators stated by scholars include urban sustainability and resilience and the green city index. Hoekstra et al. [26] included water supply, sewer, drainage, waterways, water cycle, and water sensitivity as part of their study.

Gliska–Lewczuk et al. [22] employed physicochemical parameters, whereas Gain et al. [9]

considered (a) water availability, (b) water accessibility to services, (c) safety and quality, and (d) management. The corresponding indicators are (a) the Water Security Index (WSI), which consists of the Droughts Index (DI) and groundwater depletion, (b) access to sanitation and access to drinking water for (b) above, (c) Water Quality Index (WQI) and flood frequency index (FFI) for (c) above, (d) World Governance Index (WGI) and trans-boundary legal framework and trans-boundary political tension are under criteria (d) as stated above. Dunca [27] argued that the water quality index (WIQ) and sub-WIQ are essentially the most effective determining factors used to identify pollutants sources, which include water quality classification, 90-100 as excellent, 70-90 as good, 50–70 as medium, 25-50 as bad, 0-25 as atrocious. Luo et al. [24] stated that the study handled the total removal of the solid particles as (a) Cobbles, (b) Pebbles, (c) Gravels, and (d) Sand. Patrie et al. [19] mentioned that wastewater influencing concentration is affected by;(a) spatial distribution (b) intra-day variation, (c) inter-day variability, (d) seasonality, and (e) occasional events. The physicochemical process is a medium that is used for the effective removal of EC from wastewater. Both chemical and biological methods could be used to assess environmental risk.

1.3.2. Water Pollution in Nigeria

Galadima et al. [28] focused on the causes and effects of freshwater pollution changes in selected communities in Nigeria. The sources of water pollution in Nigeria include agricultural-related pollution, oil spillage pollution, market-related pollution, and domestic home-based pollution. Water bodies are polluted in Nigeria through the contamination of leakages and other pollutants sources. In Nigeria, water pollution is caused by oil spillages, heavy metals, agricultural pesticides, household waste, sewer, toxic waste, industrial waste, and animal waste, among others [15]. Sharma [29] argued that urban and regional planning implement technology that considers changes in behavior in the water system. Urban planners required a strong methodology to associate water and soil with land-use changes within the scope of population interaction. Water shortages in urban areas are becoming an integral area of concern in many cities and countries around the world. This study evaluated the relationship between urban growth and water pollution in the Kano metropolis, Nigeria [30].

Galadima et al. [28] explained that the study focuses on the causes and effects together with its corrective measures of freshwater pollution changes in selected communities in Nigeria. The sources of water pollution in Nigeria include agricultural-related pollution, oil spillage pollution, market-related pollution, and domestic home-based pollution. Water bodies become polluted in Nigeria through contamination by leakages and other pollutants sources. In Nigeria, water pollution falls from oil spillages, heavy metals, agricultural pesticides, household waste, sewer, toxic waste, industrial waste, and animal waste, among others [15]. Sawade et al. [31] stated these as part of the study analysis, which covers ammonia analysis, nitrite and nitrate measurement, chloramine decay test, flow cytometry, detection of ammonia-oxidizing prokaryotes, and diversity profiling.

1.4. Water Pollution Parameter Treatment Techniques

Water is an essential commodity for flora and fauna survival. Urban growth and expansion, directly and indirectly, affect water bodies to different degrees, which are harmful to the ecosystem as a whole and human life specifically. This makes research contribute to the theories, principles, and techniques of water pollution mitigation. Contributing scholars include Schimidt et al. [32], who explained that long removal is the technological process used in the removal of physical treatment or processes of inactivating pathogen microorganisms. It is quite safe in providing microbiologically free and safe drinking water. A shortfall of a log includes inefficient higher average performance and underestimations of average risk [32]. Wastewater treatment technology in the work of Landreau et al. [33] focuses on the effects of physicochemical conditions on partial nitridation and anammox treatment by mobilizing ammonia oxidizer under conditions of ammonium deletion. It was studied and stated [34] that wastewater management covers the following, which is (a) sources of separation schemes for solid waste, (b) biological treatment processes, (c) thermal processes, (d) waste to energy, (e) agricultural waste circular management and valorisation, (f) industrial symbiosis, (g) economy, and (h) life cycle assessment and treatment of specific hazardous waste. Ohveira et al. [35] reported that waste-water treatment plants (WWTP) are the main sources and reservoirs of communicable antibiotic resistance to the natural environment. The application of macrophytes as a wastewater treatment technique is within the scope of Omondi [36], who postulated that macrophyte wastewater treatment (Wetland) has the following classification: (a) Float aquatic macrophyte system, (b) Emergent macrophyte treatment systems, (c) Constructed wetland, and (d) Nutrient film techniques. Choudri et al. [37] conducted a study on wastewater management. This study focuses on wastewater reuse with emphasis on microbial and chemical hazards.

1.5. Waste Pollution and Prevention Techniques

Pistocchi [38] opined that water desalination is very expensive and has significant environmental impacts. This desalination technique has advantages, whereby it can be used for irrigation, reducing groundwater abstractions, maintaining the water cycle, mitigating climate change, preserving and restoring the ecosystem, and recovering energy and minerals. Feodorov [39] integrated pollution prevention and control concepts in conjunction with European regulations, and it is based on available techniques of savage sludge treatment. Englende et al. [40] focused on water prevention technology from the context of communication/ screening removal of grit, grease and oil removal, neutralization and equation, and primary sedimentation. Englende et al. [40] highlighted secondary wastewater treatment technologies to include sludge process activation, oxidation of ponds and lagoons, filtering, moving bed bioreactors (CMMRS), and membrane bioreactors (MBRS).

1.5.1. Water Pollution and Treatment Methodologies

The methods of wastewater treatment techniques are explained by Korajkic and Harwood [41]. The methodology employed in the study includes bacterial indicator organisms, analytic methods, and specific analyses that comprise membrane filtration, enzyme substrates, specific analysis, and multiple-tube fermentation. Englende et al. [40] itemized wastewater management technologies to include the following steps, which are wastewater management goal, quality of waste management, pollutants classification, wastewater treatment methods classifications, wastewater characterization, wastewater technologies objectives, and wastewater technologies processes. Furthermore, Englende et al. [40] posited that aerobic treatment wastewater techniques include septic tanks, sludge residual treatment, thickening, sludge stabilization, and sludge dewatering, which are the ultimate disposition of solid and advanced wastewater treatment. Englende et al. [40] described wastewater treatment techniques that include removal of suspended solids, removal of organic particles, removal of inorganic particles, removal of nitrogen, removal of phosphorus, and water reuse. Shan et al. [42] argued that water demand management is highly influenced by domestic water consumption and that the proactive management level of education is integral to water consumption.

1.5.2. Water Pollution Quality Control Techniques

Eliades et al. [43] focused on the development of a sensor to promote water quality parameter monitoring. Matamoros et al. [44] revealed that inactive water treatment in small communities leads to ecosystem pollution. Technologies intensive cover (a) extended aeration system, (b) rotation biological contractors (RBS), while technologies extensive involve (a) constructed wetland (CW), and (b) waste stabilization pond (WSP). The steps involve a demonstration of small WWTPS, strategy for sampling, analytical procedure, data analysis, and aquatic risk assessment. Lukmann et al. [45] revealed that wastewater reclamation is gaining more popularity globally, although wastewater recycling is significantly cheap. However, wastewater reclamation is determined by economic efficiency. Sawade et al. [31] considered in their methodology batch details, ammonia analysis, nitrite and nitrate measurement, chloramine decay test, flow cytometry, detection of ammonia-oxidizing prokaryotes, and diversity profiling. Methods and materials employed in the study include chemicals, Al-based removal agents, removal experiments, and X-ray absorption spectroscopy [46].

1.5.3. Water Pollution Treatment Models

Water treatment models were studied by Khon et al. [47], who employed a model called photodegradation of organic pollutants. These stages are used for the results and discussion. The stages include model evaluation and calibration, photoinactivation as a function of WSP, photoinactivation as a function of seasons, photoinactivation as a function of latitudes, roles of WSP solution constituents, and virus photoinactivation as a function in natural water. Koelmans et al. [48] stated that microplastics have been recently discovered in both drinking water and its sources. The study employed the reporting microplastic in the water sample used for the study, which includes sample methods, sample size, processing of sample and its storage, preparation in the laboratory, cleaning air condition, negative control, treatment of sample, positive control, identification of polymer, reliability of the overall studies and its aspects, quality criteria and its implications, and human health risk evaluation study reliability. The methodology of the study handles the average performance of the treatment process variable log reduction evaluation, log-reduction mean hypothesis testing, and microbial risk evaluation quantitatively employing literature-based treatment performance information [32]. Zhao et al. [49] identified that the bio-electrochemical system (BES) is among the effective water treatment technology shortfall. It is very complex and often produces unsatisfactory results. Material and methods, design of reactors, buffer and media, operation of a rector, combined impacts of sulfate and carbohydrates performance (BES) evaluation, reduction of sulfate in BES characterizing, analysis of chemicals, and analysis of anodic biofilm. Polyaluminium as a coagulant is globally used in water treatment because of its high efficiency and low cost. The Al-base sorbent includes nanoclusters, polyaluminum chlorides, polyaluminum granulates, and gibbsites [45]. Sunlight plays a vital role in regulating waterborne virus infectivity in the environment. Sunlight inactivates viruses both endogenously and exogenously [46].

2. Methodology

This study employed two selected historic water pods. Historically, they were used as local building materials sites for local block-making. The two selected pods are the Shema and Hauran Wanka Ponds. Shema Pond is in Dala local government, Wudil Road Kano City in Kano, Nigeria with 12.006313333 Northings and 8.506263333 Eastings coordinates. Hauran Wanka Pond is located along the Bayero University Kano (B.U.K) Road Kofar Na'isa in Kano, Nigeria, with 11.983195 Northings and 8.50883333 Eastings coordinates. Parameters used for the water analysis include the PH value, (2) Total dissolved solids, (3) conductivity, (4) temperature, and (5) dissolve oxygen. Selection is based on their location. The sample water was analyzed in the laboratory for physicochemical elements. COD, color, hardess, salinity, suspended solid, nitrate, nitrite, iron, cobalt, copper, manganese, and nickel were considered in the study. Fig. 1 shows a flow chart of the methodology employed in the study.

Fig. 1 Flow chart of the methodology employed in the study

3. Study Area

Kano Metropolis is located geographically on Latitudes 12 ° 25 ^{I} to 12 ° 40 ^{I} N and Longitude 8° 35^{I} to 8° 45^{I} E. The metropolis is the most developed and urbanized metropolis and the most important commercial center of the entire Northern Nigeria. It has a statistical annual urban growth rate of 3%. The metropolis had an estimated population of 3.5 million in 2010. The population is projected to be 4.3 million in 2018. The population density is 1000 people per km^2. Its climate is wet and dry based on Koppen's classification [50, 51].

4. Analysis

4.1. Sampled Water Collected from Shema and Hauran Wanka Ponds

Table 1 also indicates the parameters used for the water analysis and the unit of measurement pH value. The total dissolved solid is in Mg/l, conductivity is in Ns/cm, temperature is in °C and dissolves oxygen is in Mg/l. The study indicates that the pH value of Shema Ponds is 7.62, while that of Hauran Wanka Pond is 8.1, which is higher than that of Shema Ponds. The total dissolved solid result indicates 1930 mg/l for Shema Pond and besides, and only 665Mg/l is for Hauran Wanka. The conductivity results show that 3930 Ns/cm is for Shema Pond, while 1250 Ns/cm is for Hauran Wanka Pond. The temperature in degrees Celsius indicates 35 °C for Shema Pond while 34 °C is for Hauran Wanka. The last parameter employed in the study is dissolved oxygen, which indicates the results as 4.0Mg/l for Shema Pond and 3.5 Mg/l for Hauran Wanka.

Table 1 Sampled water collected from Shema and Hauran Wanka Ponds located at the dump site in Kano Metropolis (Field survey by the authors in 2019)

S/N	Location	Shema Pond Dala Local Government, Wudil Road Kano Metropolis Nigeria		Hauran Wanka Pond BUK Road Kofar Naisa Kano Metropolis Nigeria	
1	Coordinates	12.006313333	08.50623333	11.98319500	08. 50883333
	Parameter	Units	Contents	Units	Contents
1	pH	-	7.62	-	8.1
2	Total dissolved solids	Mg/l	1930	Mg/l	665
3	Conductivity	Ns/cm	3930	Ns/cm	1250
4	Temperature	°c	35	°c	34°c
5	Dissolved Oxygen	Mg/l	4.0	Mg/l	3.5

It can be inferred that based on Table 1, Shema Pond is relatively more polluted than Hauran Wanka Pond. These results could be used by the Kano State Water Board and the Ministry of Environment, especially in the pollution control unit. This has crucial urban planning implications. This is because pollution-free water within an urban setting is highly essential and is one of the major indicators of urban dwellers' health. Research indicates that water pollution in urban centers contributes to water-borne diseases. Therefore, these are excellent data that will be used as part of the framework development.

4.2. Physicochemical Analysis Results of the Sampled Water

Elmqvist et al. [52] commented that the environmental impact of rapid urban growth is spontaneous on water bodies pollution and loss of biodiversity. Table 2 demonstrates the physicochemical analysis of the sampled pond used in the study. The physicochemical analysis covers the following parameters: COD, color, t-hardness, salinity, suspended solids, nitrates, nitrites, iron, cobalt, copper, manganese, and nickels. The results of the physicochemical analysis of the water sampled show that Shema Pond recorded a COD of 502 mg/l, whereas Hauran Wanka Pond indicated 444 mg/l. Wanka Shema Pond showed a color of 290 PtCoU, whereas Hauran Wanka Pond indicated 501 PtCoU. The result of t-hardness record of the ponds is 0 mg/l for Shema Pond and 0.16 mg/l for Hauran WankaWanka Pond. In addition, the salinity records of the ponds were 25 mg/l for Shema Pond and 20 mg/l for Hauran Wanka Pond. As for suspended solids, the analysis depicted 248 mg/l for Shema Pond and 61 mg/l for Hauran Wanka Pond.

Table 2 Physicochemical analysis results of the sampled water (Field survey by the authors in 2019)

S/N	Parameters	Units	Shema Pond	Hauran Wanka Pond
1	COD	-mg/l	502	444
2	Colour	PtCoU	290	501
3	T-hardness	mg/l	0	0.16
4	Salinity	mg/l	25	20
5	Suspended solid	mg/l	248	61
6	Nitrate	mg/l	14.8	23
7	Nitrite	mg/l	60	92
8	Iron	mg/l	1.6	1.04
9	Cobalt	mg/l	0.35	0.26
10	Copper	mg/l	0.98	0.59
11	Manganese	mg/l	3.8	2.5
12	Nickel	mg/l	5.1	3.7

Results of the study from Table 2 show that the results for nitrates of the ponds are 14.8mg/l for Shema pond, 23 mg/l for Hauran WankaWanka, and 60 mg/l for Shema pond, while 29 mg/l is recorded for Hauran Wanka pond. Additionally, iron records depict 1.6mg/l for Shema Pond, whereas 1.04 mg/l for Hauran Wanka. Furthermore, the cobalt results show 0.35 mg/l for Shema Pond and 0.26 mg/l for Hauran Wanka. The copper result, on the other hand, indicates 0.98 mg/l for Shema pond and 0.59 for Hauran Wanka pond. The manganese results of the water samples are stated as 3.8mg/l for Shema pond, and the Hauran Wanka pond is precise as 2.5mh/l. Shema Pond is relatively more contaminated and therefore more polluted. Population density and activities within the locations are contributing factors in the contamination. Figure 2 indicates the Shema and Hauran Wanka Ponds' water sampling for the study. The results obtained from this study differ from those of other research because of the population and water usage behavior of the residents. This result could be compared with Okpoli [25], who assessed PH value, temperature, turbidity, T.Ds, CODs, and EC, and Ogbojige et al. [13] employed indicators, which are turbidity, temperature and total dissolved solids (TDS), chloride ion (Cl), electrical conductivity (EC), dissolved oxygen (DO), biochemical demand (BOD), and chemical oxygen demand (COD).

Table 2 above provides an overview of the water pollution levels in each of the ponds. This is indeed a excellent indicator of this study. Water quality is directly linked to urban dwellers' health. It is also used as an indicator for assessing the quality of urban settings. These results are considered among the vital tools that could be used for a framework that could be used as quality control within the entire metropolis. This is therefore vital for urban management. Fig. 2 indicates the water sample taken for the study from the Shema and Hauran Wanka Ponds.

Fig. 2 demonstrates the sampled water-taking processes. The historic mining ponds have been turned into solid disposal sites and sewer draining points. Despite these pollutions, the ponds are used as swimming pools by children and fishing ponds by fishermen. Water is used for both domestic and industrial purposes. This is indeed a very serious environmental challenge. These required proactive measures to mitigate the environmental challenges within the metropolis. It could be inferred that existing ponds in the Kano metropolis play key roles in water provision for both domestic and industrial purposes. In addition, the ponds are not properly managed for sustainability. Therefore, this study will provide quality control guidelines for the effective management of these precious resources. The guideline also minimizes the environmental implications of the pond across the metropolis.

Fig. 2 Shema and Hawran Wanka water sample taken

Fig. 3 illustrates the comparison of the physicochemical analysis results in the values of Shema Pond. The result indicates that manganese is dominant in this pond with 56%. Iron content in this pond is 24%. The results also show that copper is the third in a hierarchy with 15%. Cobalt content in the water covers 5%, while nickel demonstrates 0%. These results provide a general overview of the pollution level of Shema Pond. The results show significant contributions of the water quality assessment in this study. This spelled out the need for quick and proactive measures to be taken concerning the environmental impacts of urban rapid growth and expansion in Kano metropolis, Nigeria.

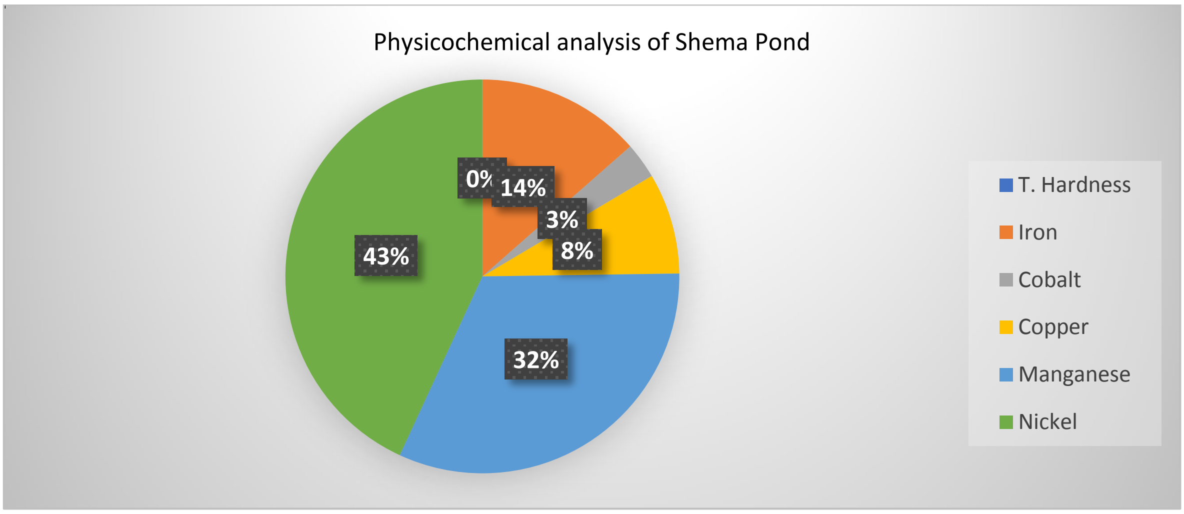

Fig. 3 Physicochemical analysis of the Shema Pond

Fig. 4 below demonstrates the physicochemical results of the analysis of the Shema and Hauran Wanka ponds in terms of three parameters, which are suspended solid, color, and COD. The results indicate 248 mg/l as the suspended solid of Shema Pond, while 61 mg/l is for Hauran Wanka Pond. Besides, the color result of Shema Pond is 290 mg/l, while Hauran Wanka consists of 501 mg/l. The figure also indicates COD as a parameter with 504 mg/l for Shema Pond, whereas Hauran Wanka records 444 mg/l. It could be inferred that the Shema Pond contained more suspended solids and COD than the Hauran Wanka Pond. In contrast, Hauran Wanka records color values far above the Shema pond color values. This result will greatly contribute to the development of the urban rapid growth management framework. This can be explained as the underwater quality indicator of the framework.

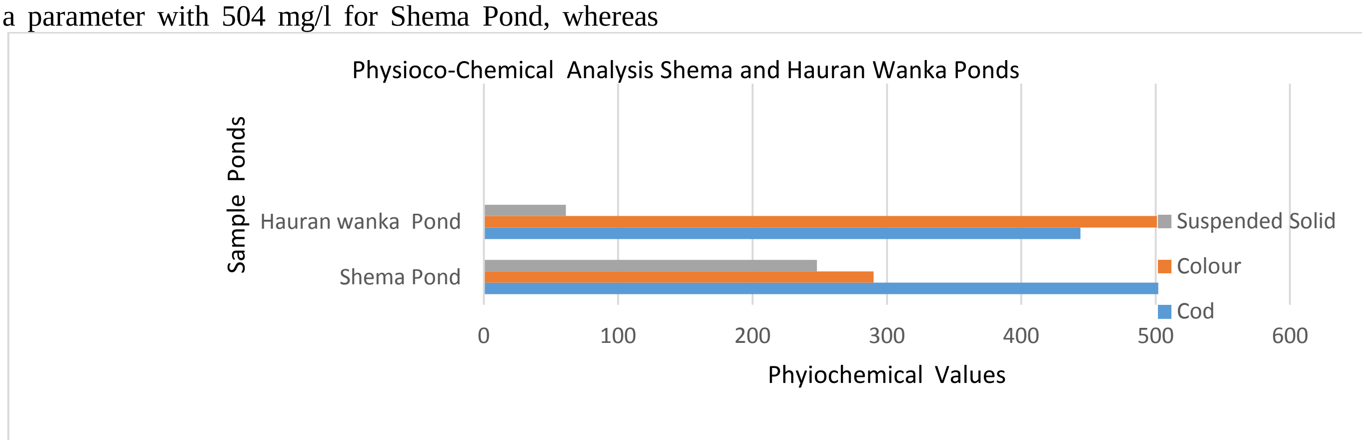

Fig. 4 Physicochemical analysis of the Shema and Hauran Wanka pond comparison

Fig. 5 indicates the comparison of the physicochemical results of the ponds with references to the salinity, nitrite, and nitrate contents. The results show that Shema Pond Salinity records as 25 mg/l and 20 mg/l is Hauran Wanka. Furthermore, the result depicts values of nitrites as 14.8 mg/l for Shema Pond, while 23 mg/l is for Huran Wanka. Nitrate physicochemical results indicate that the Shema pond covers 60 mg/l but the Hauran Wanka records 92%. Looking at the results of the two ponds, it could be deduced that the Hauran Wanka pond contains more nitrates and nitrates than the Shema pond. In contrast, the salinity content of the Shema pond is higher than that of the Hauran Wanka pond.

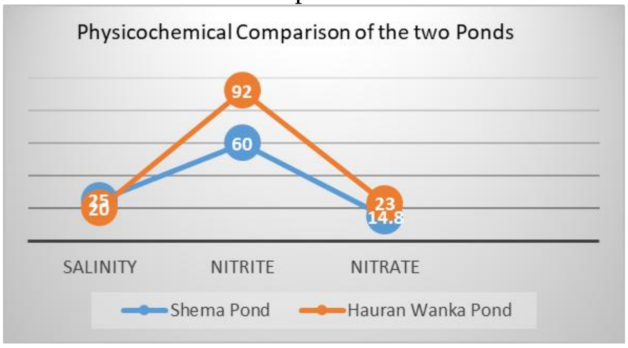

Fig. 5 Salinity, nitrite, and nitrate of the two ponds

Looking at Fig. 5 the three parameters also provide a solid foundation about concluding this aspect of the research. Water pollution assessment of the existing historic pond will improve the urban quality of the entire metropolis, and this methodology could be implemented in both developing and developed nations. These are highly essential data in urban and regional planning because the quality is proportional to the quality of health of a given population residing within a geographical location.

Fig. 6 indicates water samples taken from a pond with a heap of solid waste. The photo shows a fisherman spreading fishing tools. The figure also depicts children using one of the historic ponds as a swimming pool. This will have long-term health effects on children's health. The long-term effects will manifest in related domestic and industrial activities. This, therefore, calls for active and urgent urban and regional planning.

Fig. 6 Water samples taken from the ponds

5. Conclusion

Conclusively, the study employed only physicochemical analysis; therefore, it shows that the water analysis of the physicochemical results of the sampled ponds reveals that Shema Pond is more contaminated. Careful looking at Table 3, it could be seen that eight of the elements employed for the study's values are significantly more in Shema Pond recorded more chemical oxygen demand COD, salinity, suspended solids, iron, cobalt, copper, manganese, and nickels.

Table 3 Physicochemical results conclusions (Field survey by the authors in 2019)

Physicochemical Results and Conclusions							
Shema Pond				**Hauran Wanka Pond**			
1	COD	-mg/l	502	1	Colour	PtCoU	501
2	Salinity	mg/l	25	2	T-hardness	mg/l	0.16
3	Suspended solid	mg/l	248	3	Nitrate	mg/l	23
4	Iron	mg/l	1.6	4	Nitrite	mg/l	92
5	Cobalt	mg/l	0.35				
6	Copper	mg/l	0.98				
7	Manganese	mg/l	3.8				
8	Nickel	mg/l	5.1				

On the other hand, Hauran Wanka Pond is more polluted in terms of colour, t-hardness, nitrates and nitrites. It can be concluded that Shema Pond is more contaminated than Hauran Wanka Pond. These tremendous variations in the contamination of the two selected employed ponds are due to location differences. Shema Pond is located in a high-density residential corridor. This results in very high pressures from sewage disposal and solid waste disposal into the Shema, a historic water pond. Water pollution-related activities are more frequent within Shema Pond compared to Hauran Wanka Pond; therefore, it is more polluted based on the physicochemical results. The significantly serves as a solid foundation with regard to the subject matter, because the study is among the earliest and few scholarly researches conducted in Kano metropolis Nigeria. The result of the study could be employed in other metropolises in Nigeria, and it could also be used in African countries as a part and the global developing nations as a whole. Finally, the results of the study could academically be compared with those of advanced countries across the globe as it added to the academic value of the subject matter and its trajectory. This is achieved through both the scientific laboratory tests conducted and the body of the academic literature synthesized for the study.

References

[1] MELIAN J. H. A. Sustainable wastewater system treatment system (2018-2019). *Sustainability*, 2020, 12(1940): 1-5. https://doi.org/10.3390/su12051940

[2] LIU F., OLESEN K. B., BORREGAARD A. B., and VOLLERTSON J. Microplastic in urban highway storm water retention ponds. *Science of Total Environment*, 2019, 671: 992-1000. https://doi.org/10.1016/j.scitotenv.2019.03.416

[3] MELVIN S. D., & LEUSCH F. D. L. Removal of traced organic contaminants from domestics wastewater: a meta-analysis comparison of sewage treatment technologies. *Environmental International*, 2016, 92-93: 183-188. https://doi.org/10.1016/j.envint.2016.03.031

[4] RAJASULOCHANA P., & PREETHY V. Comparison on efficiency of various techniques in treatment of waste and sewage water–a comprehensive review. *Resources-Efficient Technologies*, 2016, 2: 175-184. https://doi.org/10.1016/j.reffit.2016.09.004

[5] AWASTHI A. K., WANG M., AWASTHI M. K., WAN Z. G, and LI J. Environmental pollution and human body burden from improper recycling of e-waste in China: a short review. *Environmental Pollution*, 2018, 243: 1310-1316. https://doi.org/10.1016/j.envpol.2018.08.037

[6] ROSA, G. L. BANADONNA, L., LUCENTINI, L., and KENMOE, S. Coronavirus in water environment; occurrence, persistence and concentration methods: a scoping review. *Water Research*, 2020, 179: 115899. https://doi.org/10.1016/j.watres.2020.115899

[7] HU J., FU W., NI F., ZHANG X., YANG C., and SANG J. An integrated processes for the advanced treatment of hypersaline petrochemical wastewater: a pilot study. *Water Research*, 2020, 182: 116019. https://doi.org/10.1016/j.watres.2020.116019

[8] VALITALO P., PERKOLA N., SEILER T., SILLANPOA M., KUCKELKORN J., and SCHULTZ E. Estrogenic activity in fresh municipal wastewater effluents. *Water Research*, 2016, 88: 740-749. https://doi.org/10.1016/j.watres.2015.10.056

[9] GAIN A. K., GIUPPONI C., and WADA Y. Measuring global water security towards sustainable development goals. *Environmental Research Letter*, 2016, 11: 124015. https://doi.org/10.1088/1748-9326/11/12/124015

[10] SANI H. B. Categories, causes and control of water pollution: a review. *International Journal of Life Science Leaflets*, 2019, 107: 4-12. http://ijses.com/wp-content/uploads/2020/10/72-IJSES-V4N9.pdf

[11] BATU A. W., SADIQ O., DADAN-GARBA A., and NAMADI M. M. Assessment of some chemical contaminants in river Kaduna, Nigeria. *African Journals of Earth and Environmental Science*, 2019: 49-62.

[12] MCCALL A.-K., BADE R., KINYUA J., LAI F. Y., THAI P. K., COVACI A., BIJLSMA L., VAN NUIJS A. L. N., and ORT C. Critical review on the stability of illicit drugs in sewer and wastewater samples. *Water Research*, 2016, 88: 933-947. https://doi.org/10.1016/j.watres.2015.10.040

[13] OGBOZIGE F. J., IGBORO S. B., ADIE D. B., and ABDULRAHMAN G. Reduction of sampling sites in rivers water quality monitoring. *Journal of Engineering Research*, 2017, 2: 32-41.

[14] BATU A. W., BELLO M. I., ATERE P. M., and EMERIBE C. N. Assessment of heavy metals pollution in the sources water from Thomas Dam, Kano State Nigeria. *Nigerian Research Journal of Engineering and Environmental Science*, 2019, 4(2): 789-800. https://www.cabdirect.org/globalhealth/abstract/20219941391

[15] SALIHU M., SHAWAI S. A. A., and SHAMSUDEEN, I. M. Effects and control of water pollution a panacea to national development. *International Journal of Environmental Chemistry*, 2017, 2(2): 43-47. http://dx.doi.org/10.11648/j.ijec.20170102.11

[16] RASHID M. A. H., MANZOOR M. M., and MUKHTAR, S. N. Urbanization and its effects on water resources an exploratory analysis. *Asian Journal of Water, Environment and Pollution*, 2018, 15(1): 67-74. http://dx.doi.org/10.3233/AJW-180007

[17] QIN H., SU Q., KHU S., and TANG N. Water quality changes during rapid urbanization in the Shenzhen River catchment: an integrated view of socio-economics and infrastructure development. *Sustainability*, 2014, 6: 7433-7451. https://doi.org/10.3390/su6107433

[18] OUYANG T., ZHU Z., and KUANG Y. Assessing impact of urbanization on river water quality in the Pearl River Delta economic zone, China. *Environmental Monitoring and Assessment*, 2006, 120(1-3): 313-325. https://doi.org/10.1007/s10661-005-9064-x

[19] PATRIE B., BARDEN R., and KASPRZYK-HORDERN B. A Review on ongoing contaminants in wastewater and the environment: current knowledge, understudied areas and recommendations for future monitoring. *Water Research*, 2015, 72: 3-27. https://doi.org/10.1016/j.watres.2014.08.053

[20] LIYANAGE C. P., & YAMADA K. Impacts of population growth on the water quality of the natural water bodies. *Sustainability*, 2017, 9: 1405. https://doi.org/10.3390/su9081405

[21] WANG R., & KALI L. Combined and synergistic effects of climate change and urbanization on water quality in the Wolf-Bay Watershed, Southern Alabama. *Journal of Environmental Science*, 2018, 64: 107-121. https://doi.org/10.1016/j.jes.2016.11.021

[22] GLIŃSKA-LEWCZUK K., GOŁAŚ I., KOC J., GOTKOWSKA-PŁACHTA A., HARNISZ M., and ROCHWERGER A. The impact of urban areas on water quality gradient along a low land river. *Environ. Monitoring Assessment*, 2016, 588: 624. https://doi.org/10.1007/s10661-016-5638-z

[23] LI J., LI Y., QIAN B., NIU L., ZHANG W., CAI W., and WU H. Development and validation of Bacteria-Based Index of Biotic. *Journal of Environmental Management*, 2017, 196: 161-167. https://doi.org/10.1016/j.jenvman.2017.03.003

[24] LUO K., HU X., HE Q., WU Z., CHEN H., HU Z., and MAZUMDER W. Impacts of rapid urbanization on water quality and macroinvertebrates communities of Streams; a case study of Liang Jiang. *Science of the Total Environment*,

2018, 62: 1601-1614. https://doi.org/10.1016/j.scitotenv.2017.10.068
[25] OKPOLI C.C. Borehole logs and physio-chemical investigation of some presumptive springs in Akoko, South-Wester Nigeria. *Environmental Research, Engineering and Management*, 2013, 3(65): 40-48. https://doi.org/10.5755/j01.erem.65.3.4351
[26] HOEKSTRA A. Y., BUURMAN J., and VAN GINKEL K. C. H. Urban water security: A review. *Environmental Research Letters*, 13: 053002. https://doi.org/10.1088/1748-9326/aaba52
[27] DUNCA A. Water pollution and water quality assessment of major transboundary rivers from Banat (Romania). *Journal of Chemistry*, 2018, 2018: 1-8. https://doi.org/10.1155/2018/9073763
[28] GALADIMA A., GARBA Z. N., LEKE L., ALMUSTAPHA M. N., and ADAM I. K. Domestic water pollutions among local communities in Nigeria causes and consequences. *European Journal of Scientific Research*, 2011, 52(4): 592-603. https://nairametrics.com/wp-content/uploads/2013/03/2012-08-30-124334_5321.pdf
[29] SHARMA S. Correlating soil and urban planning for sustainable water cycle. *Journal of Water and Land Development*, 2019, 40(I-II): 137-148. http://dx.doi.org/10.2478/jwld-2019-0015
[30] HASHIM A., GOBI K. S., and HO C.S. Urban growth air pollution CO, NO_2, and SO_2 emissions and COVID-19 in Kano metropolis Nigeria. *Journal of Xi'an University of Architecture & Technology*, 2020, XII(VII): 1385-1400. http://malrep.uum.edu.my/rep/Record/my.utm.93259
[31] SAWADE E., MONIS P., COOK D., and DRIKAS M. Is nitrification the only cause of microbiologically induced chloramine decay? *Water Research*, 2016, 88: 904-911. https://doi.org/10.1016/j.watres.2015.11.016
[32] SCHIMIDT P. J., ANDERSON W. B., and EMELKO M. B. Describing water treatment processes performance: why average long-reductions can be misleading statistics. *Water Research*, 2020, 176: 115702. https://doi.org/10.1016/j.watres.2020.115702
[33] LANDREAU M., BYSON S. J., YOU H., STAHL D. A., WINKLER M. K. H. (2020) Effective nitrogen removal from ammonium-depleted wastewater by partial nitridation and anammox immobilized in granular and thin layer gel carriers. *Water Research*, 183: 116078. https://doi.org/10.1016/j.watres.2020.116078
[34] LAI S.-K. Towards a general theory of cities. *Journal of Urban Management*, 2018, In-Press. https://www.researchgate.net/publication/326536359_Toward_a_general_theory_of_cities
[35] OHVEIRA M., NUNES M., CRESPO M. T. B., and SILVA A. F. The environmental contribution to the dissemination of carbapenem and (Flouro) quinolone resistance gene by discharged and reused wastewater effluents: the role of cellular and extracellular DNA. *Water Research*, 2020, 182: 116011. https://doi.org/10.1016/j.watres.2020.116011
[36] OMONDI D. O. Wastewater management techniques: a review of advancement on the appropriate wastewater techniques principles for sustainability. *Environmental Management and Sustainability*, 2017, 6 (1): 1-20. https://doi.org/10.5296/emsd.v6i1.10137
[37] CHOUDRI B. S., CHARABI Y., and AHMED M. Health effects associated with wastewater technology, reused and disposal. *Water Environmental Research*, 2018, 10: 1817-1848. https://doi.org/10.2175/106143015x14338845156623
[38] PISTOCCHI A., BLENINGER T., BREYER C., CALDERA C., DORATI C., GANORA D., MILLÁN M. M., PATON C., POULLIS D., SALAS HERRERO F., SAPIANO M., SEMIAT R., SOMMARIVA C., YUECE S., and ZARAGOZA G. Can seawater desalination be a win-fix to our water cycle? *Water Research*, 2020, 182: 115906. https://doi.org/10.1016/j.watres.2020.115906
[39] FEODOROV V. Moder technologies and stabilization for sewage sludge from water treatment plant. *Agriculture and Agricultural Science*, 2016, 10: 417-430. https://doi.org/10.1016/j.aaspro.2016.09.084
[40] ENGLENDE A. J., KRENKEL P., and SHAMA S. Wastewater treatment and water reclamation. *Reference Module in Erath and Environmental Science*, 2015: 639-672. https://doi.org/10.1016%2FB978-0-12-409548-9.09508-7
[41] KORAJKIC A., & HARWOOD V. J. (2016) Water supplies: microbiological analysis. *Reference Module in Erath and Environmental Science*, 2016: 458-462. https://doi.org/10.1016/B978-0-12-384947-2.00741-8
[42] SHAN Y., YANG L., PARREN K., & ZHANG Y. Household water consumption: insight from survey in Greece and Poland. *Procedia Engineering*, 2015, 199: 1409-1418. https://doi.org/10.1016/j.proeng.2015.08.1001
[43] ELIADES D. G., STAVROU D., VRACHIMIS S. G., PANAYIOTOU C. G., and POLYCARPOU M. M. Contamination events detection using multi-level threshold. *Procedia Engineering*, 2015, 199: 1429-1438. https://doi.org/10.1016/j.proeng.2015.08.1003
[44] MATAMOROS V., RODRIGUES Y., and ALBAIGES J. A comparative assessment of intensive and extensive treatment technologies for removing emerging contaminants in small communities. *Water Research*, 2016, 88: 777-785. https://doi.org/10.1016/j.watres.2015.10.058
[45] LUKMANN J., GRETHE H., and MCDONALD S. When water saving limits recycling: modelling economy-wide linkages of waste water use. *Water Research*, 2016, 88: 972-980. https://doi.org/10.1016/j.watres.2015.11.004
[46] MERTENS J., ROSE J., WEHRLI B., and FURRER G. Arsenate uptake by al nanocluster and other Al-based sorbents during water treatment. *Water Research*, 2016, 88: 844-851. https://doi.org/10.1016/j.watres.2015.11.018
[47] KHON T., MATTLE M. J., MINELLAH M., and VIONE D. A modelling approach to estimate the solar disinfection of viral indicator organism in waste stabilization ponds and surface water. *Water Research*, 2016, 88: 912-922. https://doi.org/10.1016/j.watres.2015.11.022
[48] KOELMANS A. A., MOHAMED NOR N. H., HERMSEN E., KOOI M., MINTENING S. M., and FRANCE J. D. Microplastic in freshwater and drinking water: critical review and assessment of data quality. *Water Research*, 2019, 155: 410-422. https://doi.org/10.1016/j.watres.2019.02.054
[49] ZHAO F., HEIDRICH E. S., CURTIS T. P., and DOLFING J. Understanding the complexity of wastewater: the combined impacts of carbohydrates and sulphate on the performance of bio electrochemical system. *Water Research*, 2020, 176: 115737. https://doi.org/10.1016/j.watres.2020.115737
[50] NABEGU A. B. Analysis of municipal solid waste in Kano metropolis. *Journal of Human Ecology*, 2010, 31(2):

111-119. https://doi.org/10.1080/09709274.2010.11906301
[51] HASHIM A., GOBI K. S., and HO C. S. Land uses changes, CO emission and water pollutions in Kano Metropolis Nigeria towards low carbon society. *Journal of Xi'an University of Architecture & Technology*, 2020, XII (III): 5265-5271. http://103.5.180.210/rep/Record/my.utm.93481
[52] ELMQVIST T., FRAGKIAS M., GOODNESS J., GÜNERALP B., MARCOTULLIO P. J., MCDONALD R. I., PARNELL S., SCHEWENIUS M., SENDSTAD M., SETO K. C., and WILKINSON C. *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities*. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-7088-1.

参考文:

[1] MELIAN J. H. A. 可持续废水系统处理系统（2018-2019）。可持续发展, 2020, 12(1940): 1-5. https://doi.org/10.3390/su12051940
[2] LIU F., OLESEN K. B., BORREGAARD A. B., 和 VOLLERTSON J. 城市公路雨水蓄水池中的微塑料。全面环境科学, 2019, 671: 992-1000. https://doi.org/10.1016/j.scitotenv.2019.03.416
[3] MELVIN S. D., 和 LEUSCH F. D. L. 家庭废水中追踪有机污染物的去除：污水处理技术的荟萃分析比较。环境国际, 2016, 92-93: 183-188. https://doi.org/10.1016/j.envint.2016.03.031
[4] RAJASULOCHANA P., 和 PREETHY V. 各种技术处理废水和污水的效率比较--全面综述. 资源节约型技术, 2016, 2: 175-184. https://doi.org/10.1016/j.reffit.2016.09.004
[5] AWASTHI A. K., WANG M., AWASTHI M. K., WANG Z. G, 和 LI J. 中国电子垃圾回收不当造成的环境污染和人体负担：短评。环境污染, 2018, 243: 1310-1316. https://doi.org/10.1016/j.envpol.2018.08.037
[6] ROSA, G. L. BANADONNA, L., LUCENTINI, L., 和 KENMOE, S. 冠状病毒在水环境中的发生、持久性和浓度方法:范围综述. 水资源研究, 2020, 179: 115899. https://doi.org/10.1016/j.watres.2020.115899
[7] HU J., FU W., NI F., ZHANG X., YANG C., 和 SANG J. 高盐石化废水高级处理的综合工艺:试点研究. 水资源研究, 2020, 182: 116019. https://doi.org/10.1016/j.watres.2020.116019
[8] VALITALO P., PERKOLA N., SEILER T., SILLANPOA M., KUCKELKORN J., 和 SCHULTZ E. 新鲜城市废水中的雌激素活性。水资源研究, 2016, 88: 740-749. https://doi.org/10.1016/j.watres.2015.10.056
[9] GAIN A. K., GIUPPONI C., 和 WADA Y. 衡量全球水安全以实现可持续发展目标。环境研究信, 2016, 11: 124015. https://doi.org/10.1088/1748-9326/11/12/124015
[10] SANI H. B. 水污染的类别、原因和控制:综述. 国际生命科学杂志单张, 2019, 107: 4-12. http://ijses.com/wp-content/uploads/2020/10/72-IJSES-V4N9.pdf
[11] BATU A. W., SADIQ O., DADAN-GARBA A., 和 NAMADI M. M. 评估尼日利亚卡杜纳河的一些化学污染物。非洲地球与环境科学杂志, 2019: 49-62.
[12] MCCALL A.-K., BADE R., KINYUA J., LAI F. Y., THAI P. K., COVACI A., BIJLSMA L., VAN NUIJS A. L. N., 和 ORT C. 对下水道和废水样品中非法药物的稳定性进行批判性审查。水资源研究, 2016, 88: 933-947. https://doi.org/10.1016/j.watres.2015.10.040
[13] OGBOZIGE F. J., IGBORO S. B., ADIE D. B., 和 ABDULRAHMAN G. 减少河流水质监测的取样地点。工程研究杂志, 2017, 2: 32-41.
[14] BATU A. W., BELLO M. I., ATERE P. M., 和 EMERIBE C. N. 评估尼日利亚卡诺州托马斯大坝水源中的重金属污染。尼日利亚工程与环境科学研究杂志, 2019, 4(2): 789-800. https://www.cabdirect.org/globalhealth/abstract/20219941391
[15] SALIHU M., SHAWAI S. A. A., 和 SHAMSUDEEN, I. M. 水污染的影响和控制是国家发展的灵丹妙药. 国际环境化学杂志, 2017, 2(2): 43-47. http://dx.doi.org/10.11648/j.ijec.20170102.11
[16] RASHID M. A. H., MANZOOR M. M., 和 MUKHTAR, S. N. 城市化及其对水资源的影响探索性分析. 亚洲水、环境与污染杂志, 2018, 15(1): 67-74. http://dx.doi.org/10.3233/AJW-180007
[17] QIN H., SU Q., KHU S., 和 TANG N. 深圳河流域快速城市化过程中的水质变化：社会经济与基础设施发展的综合观。可持续发展, 2014, 6: 7433-7451. https://doi.org/10.3390/su6107433
[18] OUYANG T., ZHU Z., 和 KUANG Y. 评估城市化对珠江三角洲经济区河流水质的影响. 环境监察及评估, 2006, 120(1-3): 313-325. https://doi.org/10.1007/s10661-005-9064-x
[19] PATRIE B., BARDEN R., 和 KASPRZYK-HORDERN B. 关于废水和环境中持续污染物的审查：目前的知识，未充分研究的领域和未来监测的建议。水资源研究, 2015, 72: 3-27. https://doi.org/10.1016/j.watres.2014.08.053
[20] LIYANAGE C. P., 和 YAMADA K. 人口增长对自然水体水质的影响。可持续发展, 2017, 9: 1405. https://doi.org/10.3390/su9081405
[21] WANG R., 和 KALI L. 气候变化和城市化对阿拉巴马州南部沃尔夫湾流域水质的综合和协同效应。环境科学杂志, 2018, 64: 107-121. https://doi.org/10.1016/j.jes.2016.11.021
[22] GLIŃSKA-LEWCZUK K., GOŁAŚ I., KOC J., GOTKOWSKA-PŁACHTA A., HARNISZ M., 和 ROCHWERGER A. 城市地区对低地河流水质梯度的影响. 环境。监察及评估, 2016, 588: 624. https://doi.org/10.1007/s10661-016-5638-z
[23] LI J., LI Y., QIAN B., NIU L., ZHANG W., CAI W., 和 WU H. 基于细菌的生物指标的开发和验证. 环境管理杂志, 2017, 196: 161-167. https://doi.org/10.1016/j.jenvman.2017.03.003
[24] LUO K., HU X., HE Q., WU Z., CHEN H., HU Z., 和 MAZUMDER W. 快速城市化对河流水质和大脊椎动物群落的影响；以梁江为例。整体环境科学, 2018, 62: 1601-1614. https://doi.org/10.1016/j.scitotenv.2017.10.068
[25] OKPOLI C.C. 尼日利亚西南部阿科科一些推定泉水的钻孔日志和物理化学调查。环境研究、工程及管理, 2013, 3(65): 40-48. https://doi.org/10.5755/j01.erem.65.3.4351
[26] HOEKSTRA A. Y., BUURMAN J., 和 VAN GINKEL

K. C. H. 城市水安全：回顾。环境研究信件, 13: 053002. https://doi.org/10.1088/1748-9326/aaba52
[27] DUNCA A. 巴纳特（罗马尼亚）主要跨界河流的水污染和水质评估。化学杂志, 2018, 2018: 1-8. https://doi.org/10.1155/2018/9073763
[28] GALADIMA A., GARBA Z. N., LEKE L., ALMUSTAPHA M. N., 和 ADAM I. K. 尼日利亚当地社区的生活用水污染的原因和后果。欧洲科学研究杂志, 2011, 52(4): 592-603. https://nairametrics.com/wp-content/uploads/2013/03/2012-08-30-124334_5321.pdf
[29] SHARMA S. 关联土壤和城市规划的可持续水循环。水与土地发展杂志, 2019, 40(I-II): 137-148. http://dx.doi.org/10.2478/jwld-2019-0015
[30] HASHIM A., GOBI K. S., 和 HO C.S. 尼日利亚卡诺大都市的城市增长空气污染一氧化碳，二氧化氮和二氧化硫排放和新冠肺炎。西安建筑科技大学学报, 2020, XII(VII): 1385-1400. http://malrep.uum.edu.my/rep/Record/my.utm.93259
[31] SAWADE E., MONIS P., COOK D., 和 DRIKAS M. 硝化作用是微生物诱导氯胺衰变的唯一原因吗？水资源研究, 2016, 88: 904-911. https://doi.org/10.1016/j.watres.2015.11.016
[32] SCHIMIDT P. J., ANDERSON W. B., 和 EMELKO M. B. 描述水处理工艺性能：为什么平均长期减排可能是误导性的统计数据。水资源研究, 2020, 176: 115702. https://doi.org/10.1016/j.watres.2020.115702
[33] LANDREAU M., BYSON S. J., YOU H., STAHL D. A., WINKLER M. K. H. (2020) 通过部分氮化和固定化在颗粒状和薄层凝胶载体中的[医]阿纳莫斯有效去除贫铵废水中的氮。水资源研究, 183: 116078. https://doi.org/10.1016/j.watres.2020.116078
[34] LAI S.-K. 走向城市的一般理论。城市管理杂志, 2018, 印刷中. https://www.researchgate.net/publication/326536359_Toward_a_general_theory_of_cities
[35] OHVEIRA M., NUNES M., CRESPO M. T. B., 和 SILVA A. F. 排放和再利用废水废水对碳青霉烯和（氟）喹诺酮抗性基因传播的环境贡献：细胞和细胞外脱氧核糖核酸的作用。水资源研究, 2020, 182: 116011. https://doi.org/10.1016/j.watres.2020.116011
[36] OMONDI D. O. 废水管理技术：审查有关可持续性的适当废水技术原则的进展。环境管理和可持续发展, 2017, 6 (1): 1-20. https://doi.org/10.5296/emsd.v6i1.10137
[37] CHOUDRI B. S., CHARABI Y., 和 AHMED M. 与废水技术，再利用和处置相关的健康影响。水环境研究, 2018, 10: 1817-1848. https://doi.org/10.2175/106143015x14338845156623
[38] PISTOCCHI A., BLENINGER T., BREYER C., CALDERA C., DORATI C., GANORA D., MILLÁN M. M., PATON C., POULLIS D., SALAS HERRERO F., SAPIANO M., SEMIAT R., SOMMARIVA C., YUECE S., 和 ZARAGOZA G. 海水淡化能否成为我们水循环的双赢方案？水资源研究, 2020, 182: 115906. https://doi.org/10.1016/j.watres.2020.115906
[39] FEODOROV V. 水处理厂污水污泥的现代技术和稳定化. 农业与农业科学, 2016, 10: 417-430. https://doi.org/10.1016/j.aaspro.2016.09.084
[40] ENGLENDE A. J., KRENKEL P., 和 SHAMA S. 废水处理和水回收. 地球与环境科学参考模块, 2015: 639-672. https://doi.org/10.1016%2FB978-0-12-409548-9.09508-7
[41] KORAJKIC A., 和 HARWOOD V. J. (2016) 供水：微生物分析。地球与环境科学参考模块, 2016: 458-462. https://doi.org/10.1016/B978-0-12-384947-2.00741-8
[42] SHAN Y., YANG L., PARREN K., 和 ZHANG Y. 家庭用水量：希腊和波兰调查的见解。普罗塞迪亚工程, 2015, 199: 1409-1418. https://doi.org/10.1016/j.proeng.2015.08.1001
[43] ELIADES D. G., STAVROU D., VRACHIMIS S. G., PANAYIOTOU C. G., 和 POLYCARPOU M. M. 污染事件检测使用多级阈值. 普罗塞迪亚工程, 2015, 199: 1429-1438. https://doi.org/10.1016/j.proeng.2015.08.1003
[44] MATAMOROS V., RODRIGUES Y., 和 ALBAIGES J. 对去除小社区中新兴污染物的强化和粗放处理技术的比较评估。水研究, 2016, 88: 777-785. https://doi.org/10.1016/j.watres.2015.10.058
[45] LUKMANN J., GRETHE H., 和 MCDONALD S. 当节水限制回收时：对废水利用的整个经济联系进行建模。水研究, 2016, 88: 972-980. https://doi.org/10.1016/j.watres.2015.11.004
[46] MERTENS J., ROSE J., WEHRLI B., 和 FURRER G. 水处理过程中铝纳米簇和其他铝基吸附剂对砷酸盐的吸收。水研究, 2016, 88: 844-851. https://doi.org/10.1016/j.watres.2015.11.018
[47] KHON T., MATTLE M. J., MINELLAH M., 和 VIONE D. 一种估计废物稳定池和地表水中病毒指示生物太阳消毒的建模方法。水资源研究, 2016, 88: 912-922. https://doi.org/10.1016/j.watres.2015.11.022
[48] KOELMANS A. A., MOHAMED NOR N. H., HERMSEN E., KOOI M., MINTENING S. M., 和 FRANCE J. D. 淡水和饮用水中的微塑料：数据质量的关键审查和评估。水资源研究, 2019, 155: 410-422. https://doi.org/10.1016/j.watres.2019.02.054
[49] ZHAO F., HEIDRICH E. S., CURTIS T. P., 和 DOLFING J. 了解废水的复杂性：碳水化合物和硫酸盐对生物电化学系统性能的综合影响。水资源研究, 2020, 176: 115737. https://doi.org/10.1016/j.watres.2020.115737
[50] NABEGU A. B. 卡诺大都市城市固体废物分析。人类生态学杂志, 2010, 31(2): 111-119. https://doi.org/10.1080/09709274.2010.11906301
[51] HASHIM A., GOBI K. S., 和 HO C. S. **尼日利**亚卡诺大都市的土地利用变化、二氧化碳排放和水污染向低碳社会发展. **西安建筑科技大学学**报, 2020, XII (III): 5265-5271. http://103.5.180.210/rep/Record/my.utm.93481
[52] ELMQVIST T., FRAGKIAS M., GOODNESS J., GÜNERALP B., MARCOTULLIO P. J., MCDONALD R. I., PARNELL S., SCHEWENIUS M., SENDSTAD M., SETO K. C., 和 WILKINSON C. 城市化、生物多样性和生态系统服务：挑战和机遇。斯普林格,多德雷赫特. https://doi.org/10.1007/978-94-007-7088-1.