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ARTICLE

Distribution of Respiratory Tract Infectious Diseases in Relation to Particulate Matter (PM_{2.5}) Concentration in Selected Urban Centres in Niger Delta Region of Nigeria

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ABSTRACT

Due to the visibility of soot in the environment of the Niger Delta especially Rivers State has led to the increase of Respiratory Tract Infections (RTIs) in the region, this study was undertaken to determine the relationship between Particulate Matter (PM_{2.5}) concentration and the incident of Respiratory Tract Infections (RTIs) in selected urban centres of the Niger Delta. Data on RTIs were collected from the Hospital Management Boards of the Ministries of Health of Rivers, Bayelsa and Delta States and the data for PM_{2.5} were remotely sensed from 2016 to 2019, and subsequently analyzed with ANOVA and Spearman's rank correlation statistics. The findings of this study revealed that there was significant variation in the occurrence of PM_{2.5} across the selected urban centres in the Niger Delta Region. The PM_{2.5} for the reviewed years was far above the World Health Organization's (WHO) annual permissible limit of 10 µg/m³ thereby exacerbating Respiratory Tract Infections (RTIs). The epidemiology of the RTIs showed that there are basically four (4) prominent RTI diseases: Asthma, Tuberculosis, Pneumonia and Chronic Obstructive Pulmonary Disease (COPD). The result of this study showed that the concentration of PM_{2.5} varies in all the selected cities, and the mean monthly variation (2016-2019) showed that Port Harcourt had 47.27 µg/m³ for January while Yenagoa and Asaba had 46 µg/m³ and 47.51 µg/m³ respectively for January; while the lowest mean value in the cities was seen within the month of September and October, which also had a strong seasonal influence on the concentration of PM_{2.5}. The concentration of PM_{2.5} and the number of RTIs also gradually increases in the study areas from 2016 to 2019. The study recommends that the necessary regulatory bodies should closely monitor the activities of the companies likely to cause such pollution; guild them through their operations and give prompt sanctions and heavy fines to defaulters of the accepted standards.

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1. Introduction

The atmosphere is the gaseous envelope that surrounds the earth and makes the transition between its surface and the vacuum of space ^[1,12]. Unfortunately, the atmosphere also contains pollutants that affect health ^[8]. Pollution is generally the introduction by mankind into the environment substances liable to cause hazards to human health, harm to the living organism and ecological system ^[1,9], damage to the structure or interfere with the legitimate uses of the environment ^[32,34,35]. Air pollution is on the increase especially in highly urbanized and industrialized cities ^[4,16,25]. The major air pollutants in the urban environment includes: oxides of sulphur (SO_2 , SO_x); Oxides of nitrogen (NO_x); carbon monoxide (CO); volatile organic compounds (VOCs); ozone (O_3); suspended Particulate Matter ($\text{PM}_{2.5}$ and PM_{10}) and Lead (Pb) ^[22,31]. Air pollutants can be in the form of solid particles, liquid droplets, or gases ^[32,36]. In addition, they may be natural or anthropogenic ^[19].

Particulate Matter is a complex combination of anthropogenic and biophysical materials suspended as aerosol particles in the atmosphere with major constituents like sulphate, nitrate, ammonium, organic carbon, elemental carbon, sea salt, and dust. Particulate Matter is a major air pollutant and includes all solid particles, soot and lead ^[23,30,37]. In other words, it is a combination of varying physical and chemical characteristics varying by location. Common chemical constituents of Particulate Matter include sulphate, nitrate, ammonium, other inorganic ions like ions of sodium, potassium, calcium, magnesium and chloride, organic and elemental carbon, crustal materials, particle-bound water, metals (including cadmium, copper, nickel, vanadium, and zinc) and polycyclic aromatic hydrocarbons (PAH) ^[38,39,40]. Fine Particulate Matter has become a major public health concern because of their adverse health effects ^[7] and the lungs are considered to be the primary or main organ affected, as $\text{PM}_{2.5}$ can penetrate deep into the respiratory tract and reach the alveoli ducts.

The health effect of air pollution on humans includes carcinogenicity, pulmonary tuberculosis, cerebrospinal meningitis, pneumonia, whooping cough and measles ^[8,9]. Particulate Matter can also comprise toxic pollutants, such as heavy metals, polycyclic aromatic hydrocarbons (PAHs), and other particle-bound organic compounds, which may be responsible for activating local lung damage particularly when the particles deposit on the epithelial surfaces ^[24]. Bio-distribution studies suggest translocations of Particulate Matter from the respiratory system to other organs including the liver, heart and

central nervous system, which can cause serious health effects ^[1,28].

Based on known health effects, both short-term (24-hour) and long-term (annual mean) guidelines were provided by the World Health Organisation (WHO) for $\text{PM}_{2.5}$ and PM_{10} pollutions as shown in Table 1a below, with $\text{PM}_{2.5}$ value preferred for usage over PM_{10} ^[49,50].

Table 1a. WHO Air Quality Guidelines and Interim Targets for Particulate Matter: Annual Mean Concentrations

	PM_{10} ($\mu\text{g}/\text{m}^3$)	$\text{PM}_{2.5}$ ($\mu\text{g}/\text{m}^3$)	Basis for the selected level
Interim target-1 (IT-1)	70	35	These levels are associated with about a 15% higher long-term mortality risk relative to the AQG level.
Interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower the risk of premature mortality by approximately 6% [2–11%] relative to the IT-1 level.
Interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce the mortality risk by approximately 6% [2–11%] relative to the -IT-2 level.
Air quality guideline (AQG)	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to long-term exposure to $\text{PM}_{2.5}$.

Source: WHO, 2006.

One of the major environmental problems facing the Niger Delta area is air pollution consequent on complex industrial activities such as oil and gas exploitation and flaring ^[5,25]. There have been complaints by the city dwellers about black particles settling on their cars and black dirt in their nostrils when cleaned up with a handkerchief in which cloths got stained, and a high rate of respiratory problems leading to wheezing and sneezing ^[9,10]. The rapid rate of urbanization in the Niger Delta Region through various activities such as industrialization, on-going construction works and vehicular movements have led to the constant discharge of dangerous pollutants into the atmosphere without taking proper protection and good operational methods as approved by the relevant authorities ^[4,15]. This implies that ambient air quality is one of the key environmental problems experienced by the inhabitants of towns and villages in the Niger Delta Region. In recent times, the occurrence of pollutants in the air space of the Niger Delta Region of Nigeria and beyond has been very worrisome because of natural and man induced changes and transformation without regard

to its consequences on people wellbeing^[22,44,45].

In the Niger Delta region, anthropogenic activities such as bush burning, refuse burning, traffic emission, industrial emission, chemical fertilizers industry, refinery and petrochemical complexes, gas flaring and pipeline explosion release a barrage of substances including Particulate Matter which pollute the atmosphere and have local and regional effects on materials and artefacts^[12,44]. In a research on the contamination and health risk assessment of particulate matter in Uyo; it was reported that there was no significant contamination of the particulate matter and measurable health risk associated with particulate matter at the time of the study but suggest continued monitoring as urbanization and population increases in the city^[18].

Many studies have been conducted on Particulate Matter (PM) pollutants generation, concentration, spread and its effects in the region^[10,11,14]; however, the missing link in these studies is the dearth of research on the spatial pattern of Particulate Matter pollution and the emergence of Respiratory Tract Infectious diseases in specific selected urban centres of the Niger Delta Region. Existing literature shows pieces of evidence of pollution-related diseases but the extent of spread and distribution in specific cities and the consequent health impact as it concerns Respiratory Tract Infections (RTIs) in the region is lacking. This study is focus on determining the distribution of Particulate Matter (PM) in the specific urban centres of Port Harcourt, Nchia, Yenagoa, Brass,

Asaba and Effurun; looking at the correlation between PM concentration and the incidence of Respiratory Tract Infections (RTIs) in these selected urban centres.

2. Study Area

The Niger Delta is the home to about 31 million people, which is defined officially by the Nigerian government to cover over about 70,000 km² (27,000 sq mi) and makes up 7.5% of Nigeria's land mass^[4]. It is typically considered to be located within nine coastal southern Nigerian states, which include: all six states from the South-South zone, one state (Ondo) from the South-West and two states (Abia and Imo) from the South-East; and of all the states that the region covers, only Cross River State is not an oil-producing state^[3]. The Niger Delta lies between latitudes 4° and 6° north of the equator and longitudes 5° and 9° east of the Greenwich Meridian^[42, 45].

In this study, Port Harcourt, Nchia, Yenagoa, Brass, Asaba and Effurun were purposively selected from the three Niger Delta States of Rivers, Bayelsa and Delta States. The urban centres (Port Harcourt, Yenagoa and Asaba) were selected because of their status as state capitals and the other three urban centres (Nchia, Brass and Effurun) are oil-bearing communities.

3. Methodology

The monthly Particulate Matter (PM_{2.5}) data covering 2016 to December 2019 were derived from the Satellite-Based Aerosol Optical Depth (AOD) at 550 Nanometer

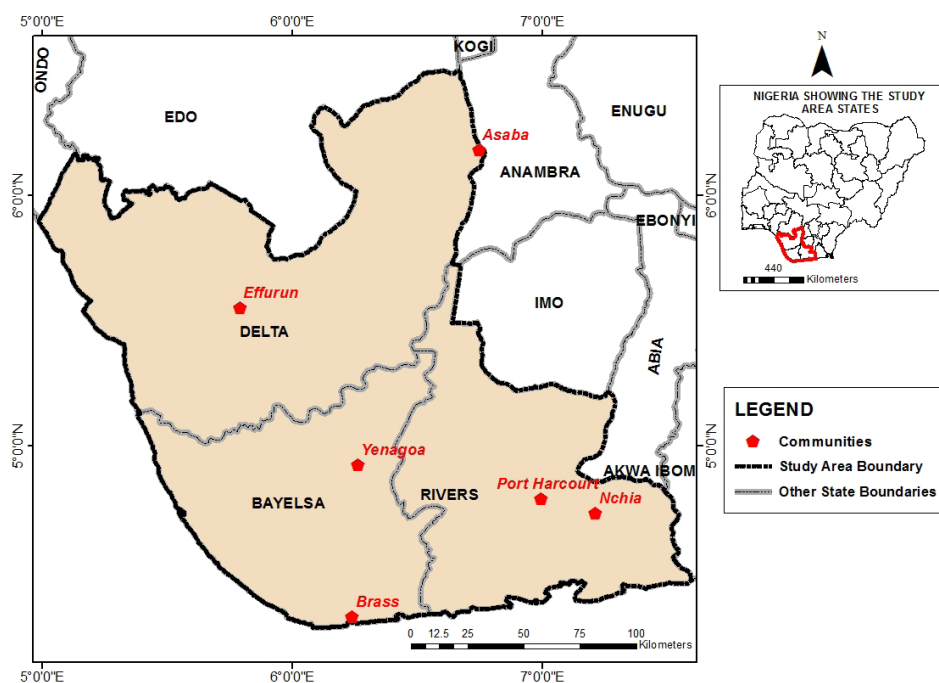


Figure 1. A Section of the Map of Nigeria showing the Study Locations (Source: Fieldwork, 2020)

(nm). The rationale for using AOD in deriving $PM_{2.5}$ was due to the unavailability of ground-based data as well as fine resolution current reanalysis estimate of $PM_{2.5}$ at the global level [6,7]. Thus, the AOD covering January 2016 to December 2019 was sourced from the Copernicus Atmosphere Monitoring Service (CAM) Emission of Atmospheric Compound and Compilation of Ancillary Data (ECCAD) website. The AOD data consists of a collection of gridded monthly emission temporal profiles from anthropogenic pollution sources categories namely energy industry, residential combustion, manufacturing industry, road transport and agriculture with guaranteed data quality and consistency [47].

The gridded AOD data which came in interoperable NETcdf format were converted to a raster layer and numerical values were extracted with the aid of x,y coordinates of the sampled locations in ARC GIS 10.1 environment. The extracted values are subsequently exported into Microsoft Excel where the $PM_{2.5}$ were computed using the formula in Equation (1).

$$PM_{2.5} = AOD * 46.7 + 7.3 \quad (1)$$

Where 46.7 and 7.13 are statistical constants for approximation [34,46].

For RTIs

The research covers 4 years (2016-2019) in selected cities of Bayelsa, Delta and Rivers states. Epidemiological data of those treated for air-borne related diseases in the respiratory clinic of government hospitals for 2016, 2017, 2018 and 2019 were collected from the health management board of each of the state Ministry of Health in the states, of which the chosen towns (Port Harcourt, Nchia, Yenagoa, Brass, Asaba and Effurun) were purposively selected because they are urban towns with industrial activities as shown on Table 1b.

4. Data Analysis and Interpretation

Table 2 shows the value of $PM_{2.5}$ in each month for the years under study for the selected urban cities in the Niger Delta States. The tables for the years (2016-2019) revealed that January has the highest concentration level followed by February in all the six selected cities and October has the least value for concentration in all the selected cities too. Seasonality must have played a major part in the trend of $PM_{2.5}$ concentration because January and February are within the dry season. The selected urban cities in Rivers state have the highest concentration in most the months of the year; this might be a result of its high industrialization status, urbanization and high population density as compared to the selected cities in

Bayelsa and Delta States.

As seen in Table 3, January and February have the highest mean value of $42.16 \mu\text{g}/\text{m}^3$ and $47.43 \mu\text{g}/\text{m}^3$ respectively indicating the concentration of Particulate Matter for the city of Port Harcourt while October with a minimum value of $14.28 \mu\text{g}/\text{m}^3$ has the lowest data. This high level of concentration of particulate matter in January and February might be a result of the fact that these months are within the dry season where meteorological impacts on the particulate matter is minimal as corroborated by Weli and Emenike [33]. Also, the column for Nchia shows that January and February over the years (2016-2019) have the highest concentration level of Particulate Matter while its lowest concentration falls within August and September. The very high concentration in those months might be a result of the increased gas flaring activities during the dry season by the multiple companies such as the Port Harcourt refinery, Indorama petrochemicals and Notore fertilizers situated in Nchia; and the PM concentration was relatively low during in the August and September during the dry season for the years under review.

Table 2 and table 3 prove that the three states of the Niger Delta are all burdened with high particulate matter concentration which is above the Department of Petroleum Resources (DPR) and World Health Organisation (WHO) annual permissible limits. The months of January and February still have the highest concentration level with maximum concentrations of $53.64 \mu\text{g}/\text{m}^3$ and $43.00 \mu\text{g}/\text{m}^3$ respectively while the least concentration level months are September and October with values of $13.40 \mu\text{g}/\text{m}^3$. The particulate matter concentration in the six selected cities of the Niger Delta states of Rivers, Bayelsa and Delta has shown similar trends where the highest concentration level is found in January and February while the lowest concentration levels are also seen in the months of September and October of the years under review (2016-2019). This trend aligned with previous studies undertaken in other parts of the world and also in Nigeria [16,17,33]. All these studies show the relationship between seasonality and atmospheric pollutants which particulate matter is a major contributor. They all proved meteorological effects and seasonality impacts on the concentration levels of the pollutants of the six cities studied in the Niger Delta where the concentration is at its peak in January and February while the lowest concentration was recorded in September and October in the studied years of 2016-2019.

Table 4 shows the 2016 particulate matter pollution amongst the selected six centres of the Niger Delta States

Table1b. Sample Size of Respiratory Tract Infection Patients in the State of the Niger Delta.

S/NO	Niger Delta States	Sampled Cities	Sampled Health Institutions	Sampled Respiratory Disease patients	Total Cases
1	Delta	Asaba	FMC, Asaba	6,001	12,341
		Effurum	General Hospital, Effurum	6,340	
2	Bayelsa	Yenagoa	FMC, Yenagoa	5,175	10,275
		Brass	General Hospital, Brass	5,100	
3	Rivers	Port Harcourt	RSUTH, Port Harcourt	17,000	27,144
		Nchia	General Hospital, Nchia	10,144	

Source: Fieldwork, 2020

Table 2. Spatio-Temporal Concentration of PM_{2.5} in the selected urban centre of the Niger Delta.**2016.**

Cities	Jan	Feb	March	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Port Harcourt	52.30	49.50	48.20	40.60	20.20	16.90	17.50	13.90	14.30	14.60	26.50	48.90
Nchia	43.20	49.10	30.20	20.00	20.10	20.30	18.02	14.70	13.10	20.60	28.50	30.10
Yenagoa	41.75	47.86	32.10	26.60	17.10	17.50	18.20	13.06	13.67	12.21	19.60	27.70
Brass	50.22	38.90	27.10	25.70	17.40	18.90	19.60	17.40	12.70	12.50	19.70	27.90
Asaba	52.50	42.60	31.60	35.10	24.10	21.70	17.10	15.60	13.40	16.40	21.60	24.10
Effurun	52.40	40.10	29.40	31.80	23.10	21.01	18.10	17.90	13.40	17.50	21.90	28.90

Source: Satellite-based Aerosol Optical Depth at 550nm (2019).

2017.

Cities	Jan	Feb	March	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Port Harcourt	42.90	49.10	33.60	26.70	19.60	19.80	19.20	40.50	15.10	13.50	20.70	29.80
Nchia	50.01	41.50	30.26	30.10	20.00	20.10	20.30	18.02	14.70	13.10	20.60	28.50
Yenagoa	50.40	45.60	30.70	24.40	16.70	15.40	16.10	11.10	11.40	10.80	17.42	25.80
Brass	40.70	46.70	32.10	26.10	18.10	19.70	21.02	15.70	14.80	12.90	19.70	28.40
Asaba	42.30	48.10	35.70	31.40	21.10	19.10	17.60	14.65	15.80	14.90	21.20	26.10
Effurun	43.00	50.70	34.50	32.10	20.40	19.10	18.60	15.30	14.51	13.40	22.20	28.80

Source: Satellite-based Aerosol Optical Depth at 550nm (2019).

2018.

Cities	Jan	Feb	March	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Port Harcourt	50.03	41.64	30.48	30.20	20.03	20.20	20.47	18.17	14.30	15.64	22.83	28.87
Nchia	52.88	41.48	30.25	29.34	19.75	20.28	20.75	18.33	14.32	15.44	22.75	29.30
Yenagoa	52.76	40.82	29.54	31.27	20.10	20.00	20.28	18.50	14.08	15.41	22.50	28.60
Brass	51.42	39.86	28.04	27.95	19.04	20.13	21.65	19.74	14.25	14.55	21.85	29.55
Asaba	51.74	41.74	32.71	36.10	24.48	20.62	18.48	16.87	14.55	17.54	22.51	25.74
Effurun	53.64	41.33	31.47	34.84	21.31	20.35	19.32	17.88	14.34	16.47	22.90	27.74

Source: Satellite-based Aerosol Optical Depth at 550nm (2019).

2019.

Cities	Jan	Feb	March	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Port Harcourt	43.41	49.49	33.61	27.19	18.34	18.34	18.75	14.30	14.92	13.36	20.80	28.87
Nchia	42.99	49.20	33.03	26.52	18.09	19.22	18.81	14.32	14.90	13.22	20.37	29.30
Yenagoa	42.85	48.96	33.28	27.71	18.29	18.75	19.31	14.08	14.97	13.31	20.78	28.60
Brass	41.08	47.14	30.89	25.19	17.27	19.86	20.23	14.25	15.16	18.88	19.20	29.55
Asaba	43.84	50.04	36.61	33.34	20.47	18.05	18.62	14.55	15.76	14.61	20.96	25.74
Effurun	44.00	50.68	35.55	31.19	19.46	18.32	19.16	14.34	15.51	14.04	21.19	27.74

Source: Satellite-based Aerosol Optical Depth at 550nm (2019).

Table 3. Mean Monthly of PM_{2.5} µg/m³ across the selected urban centres of the Niger Delta (2016-2019).

Months	Yenagoa and Brass	Asaba and Effurun	Port-Harcourt and Nchia
Jan	46.39	47.88	47.22
Feb	44.48	45.65	46.37
March	30.47	33.44	33.70
April	26.87	33.23	30.09
May	18.00	21.80	19.50
June	18.78	19.78	19.31
July	19.55	18.37	19.41
Aug	15.48	18.37	19.41
Sept	13.88	14.66	14.68
Oct	13.07	15.60	14.26
Nov	20.09	21.80	22.00
Dec	28.26	26.86	31.42

Source: Computed from data derived from Satellite-based aerosol optical depth at 550nm (2019).

Table 4. Temporal Variation of PM_{2.5} within the six centres in the Study Area between 2016 – 2019

STUDY LOCATION	2016		2017		2018		2019	
	MIN – MAX	MEAN ± SD	MIN – MAX	MEAN ± SD	MIN – MAX	MEAN ± SD	MIN – MAX	MEAN ± SD
BRASS	12.50 -50.38	21.28 ± 54.12	12.90 – 46.70	24.66 ± 35.42	14.25 – 51.42	25.33 ± 35.79	12.88 -47.14	24.43 ± 36.05
YENEGOA	12.21 – 47.86	23.95 ± 38.45	10.80 – 50.40	22.99 ± 43.93	14.08 – 52.70	26.16 ± 26.48	13.31 – 48.96	25.07 ± 35.47
ASABA	13.40 – 52.50	26.32 ± 39.68	14.65 – 58.01	25.91 ± 37.07	14.55 – 51.74	27.76 ± 38.19	14.55 – 50.04	26.02 ± 38.20
EFFURUN	13.40 – 54.40	24.46 ± 38.90	13.40 – 40.70	26.06 ± 39.63	14.34 – 53.64	26.80 ± 38.77	14.30 - 50.68	26.02 ± 40.19
PORT HARCORT	13.90 -52.60	30.28 ± 53.73	13.50 – 49.10	25.35 ± 4.72	14.30 – 50.03	26.12 ± 36.48	13.22 – 49.20	25.17 ± 38.98
NCHIA	13.10 – 49.10	25.66 ± 36.86	14.90 – 50.01	25.64 ± 30.06	14.90 – 52.88	25.88 ± 38.25	13.20 – 49.20	24.83 ± 38.61

Source: Computed from data derived from Satellite-based aerosol optical depth at 550nm (2019).

of Rivers, Bayelsa and Delta with its maximum and minimum concentration with calculated mean value and standard deviation. The data show that Port Harcourt has the highest concentration level (54.40 µg/m³) in 2016 among the cities while Yenagoa has the lowest recorded concentration level (12.21 µg/m³) in 2016. The reasons will not be far-fetched to the level of industrialization, population density and also the number of vehicular movements which all contribute to the level of air pollution in the cities between Port Harcourt and Yenagoa.

Also, the data in table 4 show that in 2017 the city of Yenagoa (10.80 µg/m³) has the least concentration of particulate matter as compared to Brass (12.90 µg/m³), Effurun (13.40 µg/m³), Asaba (14.65 µg/m³) and Port Harcourt (13.50 µg/m³) while Nchia had the maximum cumulative concentration of particulate matter in 2017, this might be as a result of the industrial activities of the refinery in Alesa Eleme, the Notore Fertiliser plant and the Eleme petrochemical plants both in Onne and Agbonchia, Aleto and Akpajo. Nchia also hosts multiple marine companies, oil and gas servicing companies plus

a population that is overwhelming with its corresponding vehicular movements. The cumulative effect of this pollution in recent times is seen in the occurrences of soot which affected residents of the Niger Delta states especially the Port Harcourt metropolis, with the first observation reported in November 2016.

The wet season is relatively longer, lasts between seven and eight months of the year, i.e. from March/April to October/November. There is usually a short break around August, otherwise termed “August Break” The August break is usually a period of the high sun with a break in precipitation in the middle of the rainy rainfall regimes or double maxima or double peaks. The analyzed data shows that at the onset of the wet season in April the concentration level is still high (180.40) because the effects of precipitation are not fully in effect, the PM_{2.5} concentration begins to reduce till it gets to the peak of the wet season which is September was the concentration gets to its minimum (86.45) and after which it begins to pick up as the dry season set in. This gradual drop in concentration level is due to the washing effects of the

rain as vehicular activities and industrial emissions are reduced within this period compared to the dry season.

Table 5. Seasonality of Particulate Matter (PM_{2.5}) Pollution in the Study Area

STUDY LOCATIONS	WET SEASON		DRY SEASON	
	MIN – MAX	MEAN ± SD	MIN – MAX	MEAN ± SD
BRASS	17.74 – 19.62	18.34	32.76 – 34.14	33.56
YENEGOA	15.13 – 19.95	17.51	33.80 – 38.84	35.38
ASABA	19.34 – 20.95	20.11	34.48 – 36.09	35.15
EFFURUN	18.86 – 20.64	19.74	34.42 – 35.97	35.20
PORT HARCOURT	16.15 – 21.71	19.03	34.77 – 45.08	37.75
NCHIA	15.90 – 21.47	17.30	28.47 – 29.44	28.92

Source: Statistical analysis from data derived from Satellite-Based Aerosol Optical Depth at 550nm (2019).

Weli and Emenike ^[33] validated this finding in their research on *Atmospheric Aerosol Loading Over the Urban Canopy of Port Harcourt City* which revealed that Particulate Matter has the highest contribution during the dry season and the lowest contribution during the wet season. It is also revealed that wet deposition can reduce air pollution by removing particulate matter and other atmospheric pollutants ^[27,29]. The dry simply denotes a region lacking in humidity. The dry season in the Niger Delta lasts for about five months from November to March. During the dry season, the Northeast trade wind, otherwise known as the tropical continental (ct), blowing over the Sahara Desert extends its dehydrating influence progressively towards the equator, reaching the southern coasts of Nigeria in late December or early January. The period is known as the “Harmattan” which is more noticeable in some years than others. The analysed data in Table 4 show that in November the metrological factors of the urban environment have much influence on atmospheric pollution but the concentration is much higher during the dry season. The onset of the dry season witness a remarkable increase in concentration (127.83) but the concentration gets to its maximum during the peak of the dry season which is January (283.00) followed by February (271.37); after these two months the concentration of Particulate Matter begins to reduce as the wet season begins to set.

Incidence of Respiratory Tract Infections in the Study Area

Table 6 shows the epidemiology of respiratory tract infection for the years under review (2016 – 2019) for Asaba and Effurun in Delta State for 10,275 patients with pneumonia accounted for 6,445 patients (62.7%), followed by tuberculosis with 1,697 patients (16.5%) while COPD had a cumulative 1,114 patients (10.8%) and the least was Asthma with 1,019 patients (9.9%). Table 2 and 3 show that Asaba and Effurun has an annual mean PM_{2.5} concentration of 26.01ug/m³ and 25.93ug/m³ respectively which are both above the DRR and WHO standards. This high PM_{2.5} concentration strongly indicates that atmospheric pollution has both environmental and health impacts; this finding is corroborated by other studies. They established a strong relationship between air pollutants including particulate matter with morbidities sources such as respiratory diseases. Zhang and Kondragunta ^[46] found that high PM_{2.5} concentration was associated with an increase in emergency department and out-patient units visit for respiratory diseases in children which is in uniform with the findings of this study.

Table 7 shows the occurrence of the different diseases of respiratory tract infection for the years under review (2016-2019) in Yenagoa and Brass. There was a total of 12,341 patients with pneumonia accounting for the highest at 63% followed by tuberculosis at 15% while COPD accounted for 11% and Asthma contributed the least number of patients at 10%. Apart from the environmental impact, the high concentration of Particulate Matter in the two urban centres which are above the WHO Limit as shown in table 2 and 3 and will also lead to serious health implications such as respiratory diseases like asthma, COPD and pneumonia. This result is validated by Nwachukwu, Chukwuocha and Igbudu ^[20] that listed respiratory diseases as some of the human impacts of atmospheric pollution. In other studies, it was said that Particulate Matter exposure leads to respiratory diseases ^[10,13]. Also, Zhang and Kondragunta ^[46] concluded that higher PM_{2.5} concentration was associated with an increase in the emergency department and out-patient units visits for respiratory diseases, while Weli and Emenike ^[33] concluded that residents in Port Harcourt which are sensitive to PM_{2.5} especially those with respiratory diseases like COPD must not be allowed to spend longer hours or reside in those part of the city.

Table 8 shows the occurrence of the different froms of the RTIs from 2016-2019 in the two government hospitals that were purposively selected; there were a total of 27,144 patients in the years under review. Pneumonia

19,233 making 70.86% followed by TB with a patient 3,229 making 11.89% COPD accounts for a total of 2,789 (10.27%) while Asthma accounted for the least number of patients 1893 (6.97%) for the years under review (2016-2019.). Table 2 and 3 show that Port Harcourt and Nchia for the period under investigation has PM concentration beyond the WHO standards which will lead to negative health challenges such as respiratory tract infections as shown in table 8, which corroborate with the studies of other researchers ^[26,34].

The pollution of Port Harcourt and Nchia is also a result of other mixed pollutants, and when particulate matter acts in synergy with other pollutants, it can cause serious health impacts especially respiratory diseases. This observation is corroborated by the study of Nwokocha, Edebeatu and Okujagu ^[21] which listed pulmonary tuberculosis, pneumonia and whooping cough as human health effects due to air pollutants. The study by Ciecewiczki and Jasper ^[48] also suggested a potential link between atmospheric pollutants the adverse health effects such as respiratory diseases.

The ANOVA table result shows that there is a significant variation in the distribution of Particulate Matter (PM_{2.5}) among the six (6) cities in the study area. The F-ratio statistic between and within the cities is 2.056 with a p-value of 0.002 which is less than 0.05 (5%) level of significance. Consequently, the result of the descriptive statistics emanating from this analysis reveals that Port Harcourt city (2016) has a very high variation, followed by Yenagoa (2017) with 16.11 and 13.20 respectively. Similarly, Effurun (2019) and Asaba (2019) have a 12.02 standard deviation each while the rest cities' location with 10.06-11.91 ranges of spread.

Table 6. Cumulative Number of RTIs Patients in Asaba and Effurun (2016-2019).

YEAR	COPD	ASTHMA	TUBECULOSIS	PREUMONIA	TOTAL
2016	240	234	337	1,371	2,182
2017	274	268	376	1,553	2,471
2018	290	237	574	1,671	2,776
2019	310	280	406	1,850	2,846
TOTAL	1,114	1,019	1,697	6,445	10,275

Source: Delta State Hospital Management Board (2019).

Table 7. Cumulative RTIs Patients in Yenagoa and Brass from 2016-2019.

YEAR	COPD	ASTHMA	TUBECULOSIS	PREUMONIA	TOTAL
2016	312	278	341	1,782	2,713
2017	369	329	404	1,733	2,835
2018	331	292	672	2,049	3,344
2019	355	368	474	2,252	3,449
TOTAL	1,367	1,267	1,891	7,816	12,341

Source: Computed from data derived from the Bayelsa State Hospital Management Board (2019).

Table 10. Summary Spearman's Rank Correlation Statistics

		Rivers	Bayelsa	Delta
COPD	Correlation Coefficient	0.400	-0.400	0.000
	Sig. (2-tailed)	0.600	0.600	1.000
	N	4	4	4
Asthma	Correlation Coefficient	-0.200	0.000	-0.600
	Sig. (2-tailed)	0.800	1.000	0.400
	N	4	4	4
Tuberculosis	Correlation Coefficient	-0.600	0.800	0.400
	Sig. (2-tailed)	0.400	0.200	0.600
	N	4	4	4
Pneumonia	Correlation Coefficient	-1.000**	0.800	0.000
	Sig. (2-tailed)	0.000	0.200	1.000
	N	4	4	4

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

Source: Fieldwork (2019).

Spearman's correlation statistics show that there is no significant relationship between RTIs and PM_{2.5} in the selected urban centres of the Niger Delta. In Rivers State, PM_{2.5} was positively correlated with COPD (r=0.400) but negatively correlated with Asthma, Tuberculosis and Pneumonia. The correlation was significant in Pneumonia (r=1.000).

In Bayelsa State, PM_{2.5} was positively correlated with RTIs except for COPD which had a negative correlation. None of the correlations was significant. Similarly, in

Table 8. Cumulative Number of RTIs Patients in Port Harcourt and Nchia from 2016-2019.

YEAR	COPD	ASTHMA	TUBERCULOSIS	PNEUMONIA	TOTAL
2016	841	552	779	4,227	5,339
2017	656	449	678	4,486	6,269
2018	634	235	899	4,877	6,445
2019	657	873	873	5843	8,031
TOTAL	2,789	1,893	3,229	19,233	27,144

Source: Rivers State Hospital Management Board (2019).

Table 9. Summary Table of the One-Way ANOVA

Sources of Variance	Sum of Square	DF	F-Ratio Calculated	F-Ratio Table	Alpha level	Result	Decision
BSS	770.332	242	2.056	0.002	0.005	Significant	H ₀ Rejected
WSS	69.667	45					
Total	840.000	287					

Source: Fieldwork (2019).

Delta State, there was a positive correlation with RTIs except for Asthma which was negative. However, none of the correlations was significant.

5. Conclusions

The distribution of Particulate Matter across the Niger Delta region is far beyond the WHO standard and therefore comes with corresponding health challenges such as Respiratory Tract Infections. It is clear from the study that PM_{2.5} pollution has adverse effects on the people and the Niger Delta environment. To a larger extent the study has established that particulate matter (PM_{2.5}) is an exacerbating or risk factor for Respiratory Tract Infection as it triggers an episode of these infections such as frequent asthma attacks when asthmatic patients are exposed to high concentrations of particulate matter in the atmosphere. The necessary regulatory bodies should closely monitor the activities of the companies likely to cause such pollution; guild them through their operation and give prompt sanctions and heavy fines to defaulters of the accepted standards.

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ARTICLE

Determination of the Thresholds of the Climatic Classification According to the Discharges in the Upper Senegal River Basin

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ABSTRACT

Floods are the most common type of natural disaster in the world and one of the most damaging. Changes in weather conditions such as precipitation and temperature result in changes in discharge. To better understand floods and eventually develop a system to predict them, we must analyze in more detail the flow of rivers. The purpose of this article is to analyze the discharges in the upper Senegal River Basin by focusing on determining the limits of the climatic classification according to past discharges. The daily discharges from May 1, 1950 to April 30, 2018 were chosen as the study period. These flow data have been grouped into annual discharges and classified as very wet, moist, medium, dry and very dry each year. Then, the flow data were divided into two seasons or periods each year: high water and low water. The statistical variables used in this study are the average, the standard deviation, the coefficient of variation and the skewness. The results of the climate classification that corresponds to a log-normal distribution indicate a total of 17 years classified as averages (25% of the series), 14 classified as wet (20.6%), 29 classified as dry (42.6 %) and 8 classified as very wet (11.8%), very dry classifications being nil. Seasonal analysis showed that the months of the high water period, such as September, had the highest flow, and the period of low water, such as May, had the lowest flow. The results of the flow analysis were then compared with changes in rainfall. The results obtained show similar climatic classifications between rainfall and flow in the basin.

1. Introduction

Floods are the most common natural disaster in the world, with 40% of natural disasters being floods ^[1]. Floods have claimed millions of lives and caused the

complete destruction of property and natural habitats. For example, in 2010, according to the Emergency Events Database ^[2], floods caused the loss of more than 8,000 lives and affected about 180 million people. The flood disasters in Pakistan and Australia are the most recent

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examples of increased human exposure to flood risk. The ability to predict floods would be an extremely valuable benefit to the world, saving thousands of lives and avoiding billions of dollars of damage ^[3].

The risk of flooding is expected to increase further due to many factors, such as demographic change, land use, climate variability and change, technological and socio-economic conditions, industrial development, urban expansion and infrastructure construction in flood-prone areas, and unplanned human settlements in flood-prone areas ^[4]. To mitigate the increasing flood risks, the approach currently proposed is integrated flood management (which is more about "living with floods") which has replaced the more traditional approach of flood defence ("flood control"). This approach aims to minimise the human, economic and ecological losses from extreme floods while maximising the social, economic and ecological benefits of ordinary floods ^[4].

One method of determining the risk of flooding is to carry out a flow analysis. Flow analyses have been carried out all over the world. A study of the impact of climate variability on the flow of the Yellow River in China showed that precipitation and temperature affected the flow ^[5]. Their study of annual precipitation in La Nina and El Nino years showed that, for small increases in precipitation, the percentage change in streamflow is less than that of precipitation for the Yellow River. These results provide a resource for watershed water resource planning and management to keep the river functioning properly. Another study was conducted in an arid region of northwest China. It was found that climate variability accounted for about 64% of the reduction in mean annual flow, with most of the reduction due to reduced rainfall ^[6]. Their findings also concluded that the discharge of the Shiyang River is more sensitive to variations in precipitation than its potential evaporation.

Given the succession of extreme climatological (droughts and floods) and hydrological (high and low water) episodes, numerous studies have been carried out on the Senegal River basin ^[7-10]. These different studies have therefore analysed the data to characterise climate change in this basin. The Senegal River basin has experienced climatic variability since the 1970s, marked by a decrease in precipitation ^[7], which has resulted in a significant decrease in surface discharge ^[10], as illustrated by the years 1983 and 1984, when discharge even stopped in Bakel. This decrease in discharge has harmed many sectors of activity (agricultural production, industry, drinking water supply, navigation, etc.), placing the basin in an unprecedented ecological crisis ^[11].

In keeping with its mission to preserve the balance of

ecosystems in the Senegal River basin, the Organisation pour la Mise en Valeur du fleuve Sénégal (OMVS) monitors the river's water levels on a preventive basis through regular hydrometric surveys. To remedy this drop in discharges, ensure better control of water resources and encourage development actions, the OMVS has carried out major developments on the Senegal River, notably the Diama (1986) and Manantali (1988) dams. In this context of hydrological deficit, the implementation of these works allowed the control of discharges on the Bafing section and the management of floods in the downstream part of the Senegal River basin (from Bakel). However, new studies have highlighted the increase in rainfall and discharge in the area, which points to an improvement in the hydrological regime ^[10,12,13] and an increase in flooding.

Changes in climatic conditions such as precipitation, temperature, wind and evaporation can therefore cause large and rapid changes in river flow ^[14], hence the need to predict and analyse river floods based on historical data. In order to conduct a streamflow analysis, it is necessary to collect sufficient streamflow data. Entities such as OMVS collect flow data along the Senegal River and store it in databases.

In a climatic context marked by a possible increase in the occurrence and impact of floods in the coming years, it is essential to be able to analyse hydrological variables in order to propose adaptation measures to the populations. It is within this framework that the present study was initiated in the upper Senegal River basin. The article aims to analyse the discharges in the upper Senegal River basin by classifying the climate of each river basin according to the discharges. This is of paramount importance because floods are natural risks against which it is necessary to protect oneself by prevention as well as by forecasting. Moreover, the rational management of the Senegal River basin and the Manantali dam, and the control of floods in the valley requires a better knowledge of the discharges in the basin.

2. Study Area

The Senegal River, some 1,700 km long, drains a basin of 300,000 km², straddling four countries: Guinea, Mali, Senegal and Mauritania (Figure 1). It runs from 10°20' to 17° N and from 7° to 12°20' W and is made up of several tributaries, the main ones being the Bafing, Bakoye and Falémé rivers, which have their sources in Guinea and form the upper basin ^[15] (Figure 1). The Senegal River thus formed by the junction between the Bafing and the Bakoye, receives the Kolimbiné and then the Karokoro on the right and the Falémé on the left, 50 km upstream from Bakel. In the southern part of the basin, the density of the

hydrographic network bears witness to the impermeable nature of the land ^[16,17].

The Senegal River basin, like the entire intertropical belt, has experienced climatic upheaval since the 1970s ^[8]. Various studies on this basin have already shown the effects of climate change with modifications of its hydrological regime from 1970 onwards ^[7-10,18-23]. In order to remedy the effects of climate change and to cope with changes in the hydrological regime, a series of developments (Diamas and Manantali) were initiated, completely transforming the hydrological dynamics of the Senegal River basin.

The basin is generally divided into three entities: the upper basin, the valley and the delta, which are strongly differentiated by their topographical and climatological conditions. The upper basin, our study area, extends from the sources of the river (the Fouta Djallon) to the confluence of the Senegal and Falmé rivers (downstream of Kayes and upstream of Bakel). It is roughly made up of the Guinean and Malian parts of the river basin and provides almost all the water inflow (more than 80% of the inflow) from the river to Bakel, as it is relatively wet ^[15]. The rains fall between April and October in the mountainous southernmost part of the basin, particularly in the Guinean part of the basin, and cause the annual flooding of the river between July and October.

3. Data and Methods

3.1 Data

The database of stations to be retained in the upper Senegal River basin for this study should contain daily flow series that meet two important criteria: the length of the chronicles on the one hand (covering the longest possible period), and the quality of the data on the other (as few missing data as possible). This was the case at the station selected for this study. The hydrometric data were made available to us by the Organisation pour la Mise en Valeur du Fleuve Sénégal (OMVS). These data relate to the daily flows (from 1950 to 2018) from which the annual and seasonal flows are calculated. From the annual and seasonal flows the climatic classification was made.

3.2 Methods

3.2.1. Statistical Analysis

Average

The average of a list of numbers is the sum of the list divided by the number of elements in the list ^[24]. The average is the most commonly used type of average and is often simply called the mean. Averaging is used to calculate the seasonal average flow. The average (μ) is defined as follows:

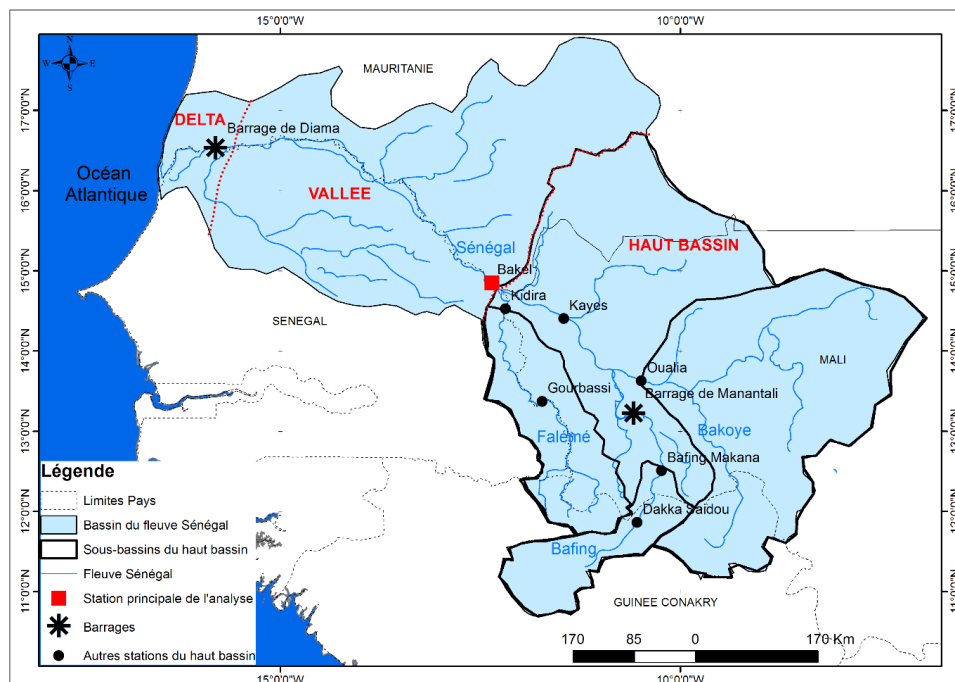


Figure 1. Location of the Senegal River watershed and its upper basin

$$\mu = \frac{1}{n} \sum_{i=1}^n x_i$$

Standard deviation

The standard deviation (σ) of a data set is the square root of its variance. The variance of a data set is the average of the squared deviation of that variable from its expected value or mean. Variance is simply the measure or amount of variation in the values of a set ^[24]. In other words, the standard deviation is the calculation of the deviation of a data set from its mean. The standard deviation was used to define the climate classification for the annual analysis.

$$\sigma = \sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - \mu)^2}$$

Variability

Variability is the amount by which data points in a statistical distribution or data set diverge from the mean value, as well as the extent to which these data points differ from each other ^[25]. Variability was used to determine which season (or period) was most different from other seasons.

$$Variability = \frac{\sigma}{\mu}$$

Asymmetry

In probability and statistics, skewness is a measure of the degree of skewness of distribution ^[24]. A distribution is considered skewed if the tail on one side of the distribution is longer than the tail on the other side. If the data are skewed in the direction of higher values, there is positive skewness. If the opposite is true, there is a negative skewness. In a perfect distribution, there will be no skewness and the skewness value will be zero. The skewness was used to determine whether the data corresponded to a normal or log-normal distribution.

3.2.2 Definitions

This section will discuss how a water year was defined

Table 2. Monthly values of discharge and CMD at Mako station (1950-2018)

	M	J	J	A	S	O	N	D	J	F	M	A	AN
Q (m ³ /s)	87,1	152	530	1627	2396	1150	437	226	154	121	107	94,5	590
CMD	0,15	0,26	0,90	2,76	4,06	1,95	0,74	0,38	0,26	0,21	0,18	0,16	1,00
Periods	Low water		High water				Low water						

and then discuss how the annual cumulative streamflow was divided into climatic classifications. Finally, the way in which the data was divided into seasons will be explained.

Climate classification

To determine the limits of the climate classification, the mean and standard deviation of the annual discharge of the data set were manipulated. Table 1 shows the limits of the climate classification as a function of discharge ^[3].

Table 1. Limits for climate classification as a function of discharge

Limits	Parameters	Classification
Below	Mean - 1.5 X Standard deviation	Very dry
Between	Mean - 0.5 X standard deviation & Mean - 1.5 X standard deviation	Dry
Between	Mean + 0.5 X standard deviation & Mean - 0.5 X standard deviation	Average
Between	Mean + 1.5 X standard deviation & Mean + 0.5 X standard deviation	Wet
Above	Average + 1.5 X Standard deviation	Very wet

Seasonal classification

To carry out a seasonal classification, a segmentation of the data series on a monthly scale was carried out. For this data segmentation, the analysis of the monthly evolution of the basin's discharge and the monthly flow coefficient (MFC, ratio between monthly and annual flow) (Table 2) at the Bakel station over the period 1950-2018, divides the series into two components: a low water period (May-July and November-April) and a high water period (August-October). For this study, although July has a CMD <1 (0.90), it is counted in the period of high water. This choice is explained by the importance of its average flow (which is 530 m³/s).

After determining the character of each year (very humid, humid, medium, dry or very dry), an analysis

was carried out on the period of high water and that of low water. It should also be noted that in the tropical environment of the northern hemisphere, a hydrological year is defined from May 1 to April 30. Once the data was separated by year, the daily data for each year were added together to obtain a cumulative flow for that water year. The seasons or periods were compared with each other in relation to their respective climatic classifications. Finally, all the results were compiled in a single graph in order to visually compare the seasonal flows in different climatic classifications.

4. Results and Discussion

4.1 Analysis of the Flow on an Annual Scale

Figure 2 presents the annual flow or modulus of the Senegal River basin from 1950 to 2018. The results indicate that the year 1950-51 recorded the highest flow with $1156 \text{ m}^3/\text{s}$ (i.e. a volume of $36,466,640,687 \text{ m}^3$). On the other hand, the year 1987-88 had the lowest annual modulus with a value of $226 \text{ m}^3/\text{s}$ (i.e. a flow volume of $7,125,906,466 \text{ m}^3$). Depending on the flow rate of each year from 1950 to 2018, Figure 2 shows the threshold for a very wet, humid, average, dry or very dry year, as defined in Table 1. The average annual discharge is $590 \text{ m}^3/\text{s}$ (or a volume of $18,605,561,755 \text{ m}^3$). Any year in which the discharge is greater than the mean plus one and a half times the standard deviation (represented by the red line) is considered a very wet year. Any year with a discharge between the mean plus one and a half times the standard deviation (red line) and the mean plus half the standard deviation (represented by the green line) is

considered a wet year. Years with an elapsed discharge between the mean plus half the standard deviation (green line) and the mean minus half the standard deviation (represented by the blue line) are considered average years. Years with cumulative discharge between the mean minus half the standard deviation (blue line) and the mean minus one and a half times the standard deviation (represented by the orange line) are considered dry years. Years with discharge below the mean minus one and a half times the standard deviation (orange line) are considered very dry years.

Threshold indicators are lines on the graph that indicate threshold values for very wet (above the red line), wet (between the red and green lines), medium (between the green and blue lines), dry (between the blue and orange lines) and very dry (below the orange line).

The results of the climatic classification (Tables 3 and 4) which correspond to a log-normal distribution indicate a total of 8 years classified as very humid (11.8% of the series have an annual flow $> 969 \text{ m}^3/\text{s}$), 14 years classified as wet (20.6% of the series have an annual flow between 716 and $969 \text{ m}^3/\text{s}$), 17 years classified as average (25% of the series have an annual flow between 464 and $716 \text{ m}^3/\text{s}$) and 29 years classified as dry (42.6% of the series have an annual flow between 211 and $716 \text{ m}^3/\text{s}$). On the other hand, there is no year included in the category of dry years (no year recorded an annual flow $< 211 \text{ m}^3/\text{s}$).

4.2 Seasonal Flow Analysis

From the information collected during the annual-scale analysis of the flow over the upper Senegal River basin, the seasonal-scale analysis could be carried out. The

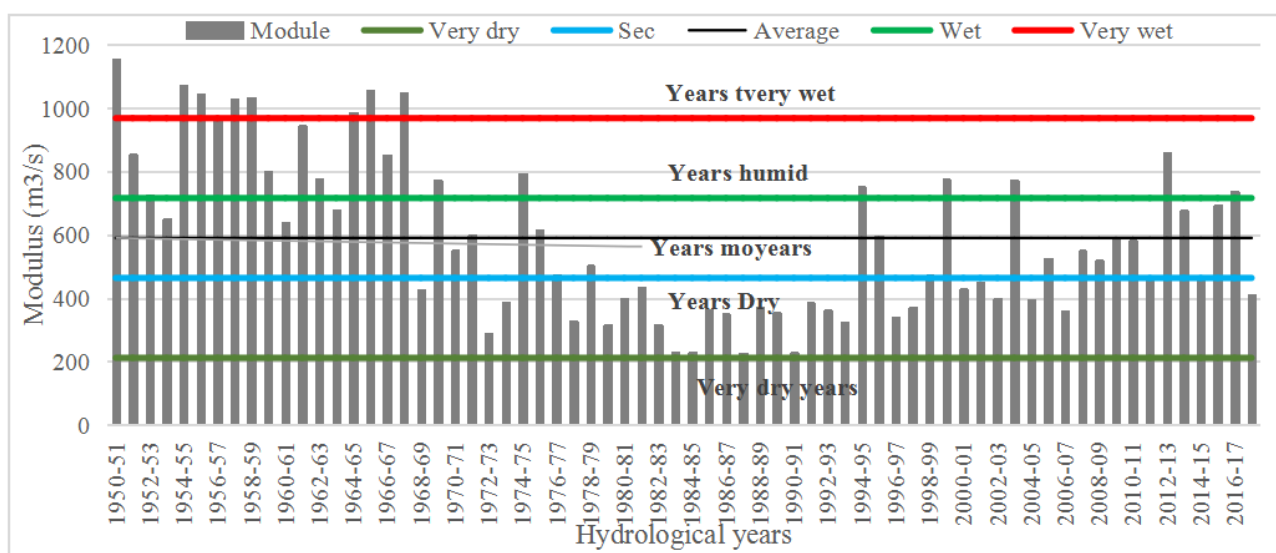


Figure 2. Annual discharge of the upper Senegal River basin from 1950 to 2018 with threshold indicators.

annual scale analysis was mainly based on the climate classification for each year given in Table 3 (very humid, humid, medium, dry or very dry). Each year has been divided into two seasons or periods: the high water period (July to October) and the low water period (November to June). Due to the absence of hydrological years classified as very dry, the years in the series were divided into four different series according to their climatic classification (very humid, humid, medium and dry) on which certain parameters (such as volume mean and total flow rates, and standard deviation) were calculated (Tables 5 and 6). Figure 3 was compiled from these tables, using the cumulative seasonal average volume of each classification, to visually compare the seasonal differences within each classification.

Table 3. Classifications of very wet, wet, medium, dry and very dry climate according to the annual flow of the upper Senegal River basin from 1850 to 2018

Very wet	Wet	Average	Dry	Very dry
1950-51	1951-52	1953-54	1968-69	1992-93
1954-55	1952-53	1960-61	1972-73	1993-94
1955-56	1956-57	1963-64	1973-74	1996-97
1957-58	1959-60	1970-71	1977-78	1997-98
1958-59	1961-62	1971-72	1979-80	2000-01
1964-65	1962-63	1975-76	1980-81	2001-02
1965-66	1966-67	1976-77	1981-82	2002-03
1967-68	1969-70	1978-79	1982-83	2004-05
-	1974-75	1995-96	1983-84	2006-07
-	1994-95	1998-99	1984-85	2011-12
-	1999-00	2005-06	1985-86	2014-15
-	2003-04	2007-08	1986-87	2017-18
-	2012-13	2008-09	1987-88	-
-	2016-17	2009-10	1988-89	-
-	-	2010-11	1989-90	-
-	-	2013-14	1990-91	-
-	-	2015-16	1991-92	-

Table 4. Threshold values for climatic classifications of annual discharge in the upper Senegal River basin from 1950 to 2018

Parameters	Discharge in m ³ /s	Volume in m ³	Classification	Number of years
Mean - 1.5 X Standard deviation	211	6 667 245 162	Very dry years	0
Mean - 0.5 X Standard deviation	464	14 626 122 891	Dry years	29
Average	590	18 605 561 755	Average years	17
Mean + 0.5 X Standard deviation	716	22 585 000 619	Wet years	14
Average + 1.5 X Standard deviation	969	30 543 878 347	Very wet years	8

Of the series of very wet years (8 in total), the high water period had the highest average cumulative discharge volume, with an average value of 28,508,577,481 m³. The highest seasonal volume for the high water period was 32,480,447,043 m³ in 1950-51. The lowest seasonal volume for the high water period was recorded in 1964-65 and amounted to 26,982,296,643 m³ (Table 5).

The season with the lowest average flow in the very wet years was the low water period, with an average value of 4,811,405,037 m³. In contrast to the high water period, the year 1950-51 had the lowest cumulative flow volume of the low water period, with a value of 4,080,835,212 m³. The highest value of cumulative flow volume was recorded in 1958-59 with a value of 5,568,263,796 m³ (Table 5).

Similar to the very wet years, of the series of wet years (14 in total), the high water period had the highest average cumulative discharge volume, with an average value of 20,863,591,136 m³. The highest seasonal volume for the high water period was 26,724,790,081 m³ in 1962-63. The lowest seasonal volume for the high water period was reached in 1994-95 and was 14,261,782,778 m³ (Table 5).

The season with the lowest average flow for wet years was also the low water period with an average volume of

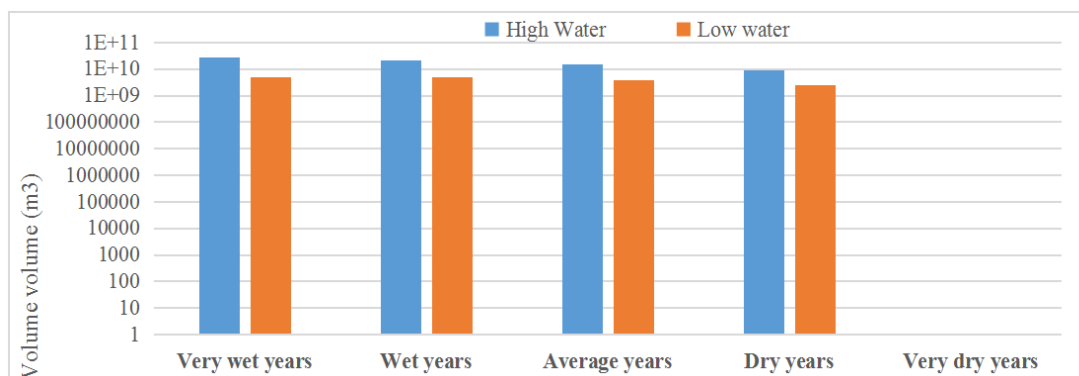


Figure 3. Comparison of the average seasonal volume of the upper Senegal River basin according to the climatic classifications of the annual flow from 1950 to 2018

4,869,886,574 m³. In contrast to the high water period, 2018 had the highest cumulative volume of the low water period in 1994-95, with a value of 9,490,712,162 m³. The lowest value of cumulative discharge volume was recorded in 1974-75, with a value of 1,942,349,044 m³ (Table 5).

Of the average year series (17 in total), like all other climatic classifications, the high water period had the highest average cumulative discharge volume, with an average value of 14,459,817,733 m³. The highest seasonal volume for the high water period was 18,191,977,926 recorded in 1963-64, while the lowest seasonal volume is recorded in 2004-05 with a value of 8,062,053,136 m³ (Table 6).

Again, the low water period was the period with the lowest average flow volume for average years, with a value of 3,740,751,795 m³. The year 2015-16 had the highest cumulative flow volume for the low water period with a value of 6,126,983,474 m³. The lowest cumulative volume value for the low water period was in 1971-72, with a value of 1,798,816,713 m³ (Table 6).

Finally, in the dry year series (the longest in the series with a total of 29 years), like all other climatic classifications, the high water period had the highest average cumulative discharge volume, with an average value of 8,915,192,861 m³. The highest seasonal volume for the high water period was recorded in 1981-82 with a value of 12,529,035,933 m³, while the lowest seasonal volume is recorded in 1990-91 with a value of 5,128,414,555 m³ (Table 6).

The season with the lowest average flow in the dry years was the low water period, with an average value of 2,564,206,494 m³. Here, the year 1985-86 had the lowest cumulative flow volume of the low water period, with a value of 760,601,473 m³. In contrast, the highest cumulative flow volume was noted in 2014-15 with a value of 5,256,428,025 m³ (Table 6).

All climatic classifications were grouped together to visually compare each (Figure 4.a). The high water period indicates the highest level and the low water period the lowest flow. The highest mean volume during the high water period was 20,863,591,136 m³ in very wet years and the lowest mean volume was 8,915,192,861 m³ in dry years. There is therefore a clear difference between the period of high water and that of low water. Over both periods, very wet years have the highest average volume followed first by wet, then medium and finally dry years.

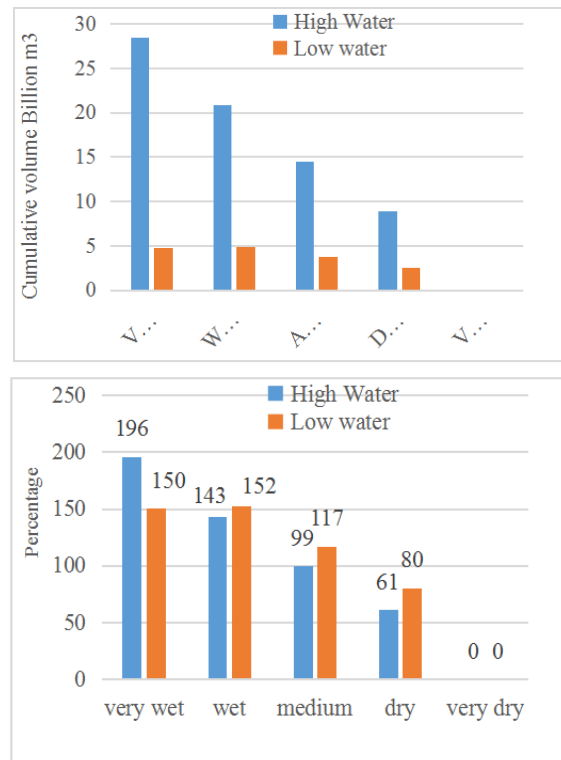


Figure 4. Cumulative elapsed volume for each season in the respective climate classification (a) and percentage of volume in their respective climate compared to the period average (b)

To determine the most variable period according to the classification, the period of high water and that of low water represented in the form of a percentage relative to the mean volume flowed over the series (Figure 4b). The results show that the months of the high water period are the most variable for the very humid and dry type of climate and less variable than those months of the low water period for the humid and medium type climates.

The largest positive difference was observed during the high water period of very wet years, with the average seasonal flow representing 196% of the overall average high water period, or 1.96 times the overall average seasonal flow. The largest negative difference was also observed in the high water period of dry years, with the average seasonal flow volume being 61% of the overall average high water period, or 0.61 times the overall average seasonal flow volume. The average seasonal volume closest to the overall average was found in the middle years, in both the high and low water months. In these average years, the average seasonal volume in the high water period is 99% of the overall average, or 0.99 times the overall average seasonal volume. This indicates that the high water months had the greatest effect on the climate classification of a year [3].

Table 5. Comparison of cumulative seasonal discharge volume in very wet and wet years in the upper Senegal River basin from 1950 to 2018

Very wet years			Wet years		
Date	High water	Low water	Date	High water	Low water
1950-51	32480447043	4080835212	1951-52	20714356815	6353683152
1954-55	28814235841	5122270874	1952-53	19772536314	3292613032
1955-56	27923797451	5191262891	1956-57	26557865280	3878324395
1957-58	27071297278	5447003585	1959-60	21795583686	3541566286
1958-59	27197648646	5568263796	1961-62	26724790081	3123741336
1964-65	26982296643	4142754401	1962-63	20961789128	3621121418
1965-66	29244412795	4103528654	1966-67	22370091842	4659990766
1967-68	28354484152	4835320887	1969-70	19982851205	4470555493
			1974-75	23193114906	1942349044
			1994-95	14261782778	9490712162
			1999-00	19132055625	5410795246
			2003-04	19074951354	5421971669
			2012-13	20060015038	7154887851
			2016-17	17488491846	5816100191
Total	228068619848	38491240300	Total	292090275898	68178412040
Average	28508577481	4811405037	Average	20863591136	4869886574
Standard deviation	1808321356	621086276,2	Standard deviation	3271786322	1939180436
CV	0,06	0,13	CV	0,16	0,40

(Purple = Lowest cumulative seasonal elapsed volume value; Green = Highest cumulative seasonal elapsed volume value; Yellow = Average cumulative seasonal elapsed volume value)

4.3 Comparison of the Climatic Classification of Discharge and Precipitation

The climatic classifications of discharge in the upper Senegal River basin were compared with the evolution of rainfall (Figure 5). The results obtained show similar climatic classifications between rainfall and discharge in the basin. The analysis of Figure 5 shows that the discharge of the rivers gradually changes with changes in rainfall. The study of the climatic framework is fundamental, as indicated by the work of Faye^[26] and Faye and Mendy^[27]. Precipitation indices highlight a great climatic variability in Senegal with the presence of two periods: a very rainy period marked by abundant rainfall during the 1950s and 1960s and a dry period characterised by drought during the 1970s and 1980s. On the other hand, during the 2000s, it was noted in the basins that an

increase in rainfall predicted improved rainfall patterns in the basin compared to the dry period of the previous decades (Faye, 2018)^[26]. However, the persistence and sustainability of the increase have yet to be proven, as the sufficiently long climatological scale is thirty years^[28]. For the discharge indices, they are positive for very wet and wet years and negative for dry years, while for average years, the indices alternate between positive and negative values, while being close to 0.

From the graph, it can be seen that the discharge in the very wet and wet years (with discharge indices up to 2.2 in 1950-51) generally coincides with the years with the most surplus rainfall (with rainfall indices up to 2.14 in 1954-55). These years are located in the decades (1950s and 1960s) of abundant rainfall and in the 2000s when a return to rainfall is noted (with rainfall indices as

Table 6. Comparison of cumulative seasonal discharge volume in average and dry years in the upper Senegal River basin from 1950 to 2018

Average years			Dry years		
Date	High water	Low water	Date	High water	Low water
1953-54	17298472319	3259551379	1968-69	11068202897	2413370185
1960-61	17060388481	3192811096	1972-73	7353846142	1748689181
1963-64	18191977926	3287002732	1973-74	10591240337	1648253793
1970-71	15352579549	2083562393	1977-78	9330249886	1049473124
1971-72	17174579913	1798816713	1979-80	8511751289	1494356589
1975-76	17437245800	1989714616	1980-81	11509050208	1125116632
1976-77	11404551873	3608206129	1981-82	12529035933	1266345430
1978-79	13834100567	2132674264	1982-83	8905830239	1089442354
1995-96	13845593058	4981265100	1983-84	6361865272	958040527
1998-99	11998513995	2864857395	1984-85	6480336962	787259306
2004-05	8062053136	4446905544	1985-86	10750196412	760601473
2007-08	13484301126	3892337038	1986-87	9829392611	1226270513
2008-09	12177025916	4271745608	1987-88	5942798167	1201907530
2009-10	13660415078	4884842204	1988-89	10380274263	1364635854
2010-11	12867387843	5510811789	1989-90	9229165033	1964603864
2013-14	16154259846	5260693049	1990-91	5128414555	2079370393
2015-16	15813455035	6126983474	1991-92	8520723509	3663431017
			1992-93	6893231297	4473568271
			1993-94	7271636566	2918726743
			1996-97	7763706163	2998131661
			1997-98	9491320821	2253688804
			2000-01	10265275573	3270922208
			2001-02	10079693583	4126031897
			2002-03	8787377664	3771500222
			2005-06	11435592970	5210938884
			2006-07	7083953249	4250448138
			2011-12	9811074251	4864271127
			2014-15	9385441932	5256428025
			2017-18	7849915197	5126164576
Total	245816901461	63592780523	Total	258540592980	74361988321
Average	14459817733	3740751795	Average	8915192861	2564206494
Standard deviation	2703191991	1334183053	Standard deviation	1849120722	1513949112
CV	0,19	0,36	CV	0,21	0,59

(Purple = Lowest cumulative seasonal elapsed volume value; Green = Highest cumulative seasonal elapsed volume value; Yellow = Average cumulative seasonal elapsed volume value)

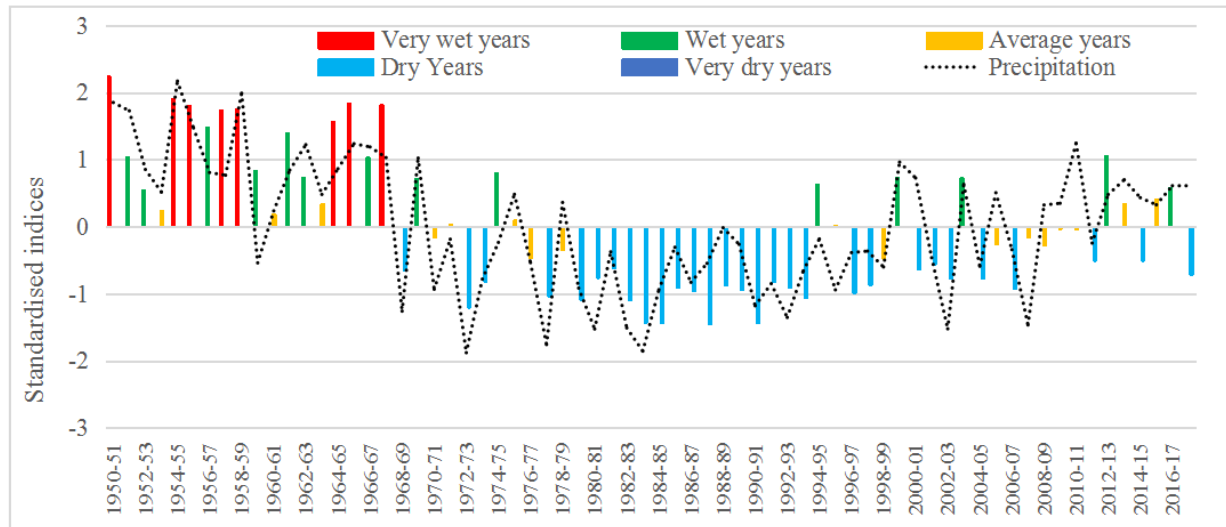


Figure 5. Comparative evolution of rainfall and climate classification of discharge in the upper Senegal River basin from 1950 to 2018 (For ease of comparison, rainfall and discharge have been standardised through the mean and standard deviation of the series)

high as 1.24 in 2010-11). In contrast, dry year discharge (the longest series) is noted over the decades (1970s and 1980s) characterised by a rainfall deficit due to drought. However, some climatic discharge classifications can sometimes be contradicted by rainfall analysis. For example, in 1959-60, the discharge is classified as a wet year (with a discharge index of about 0.84), while there was a rainfall deficit (with a rainfall index of -0.54). The same is true for the year 1978-79, where rainfall is surplus to the series average (rainfall index of 0.36), while discharge is deficit (with a discharge index of -0.34 and a year classified as average).

5. Discussion

Annual scale

The objective of the annual discharge analysis of the upper Senegal River basin was to be able to classify each year as very wet, wet, average, dry or very dry. After analysing the results, this could be achieved. The cumulative annual discharge volume was used for the classification by year, as opposed to the average annual discharge volume. The reason for this was to more accurately represent the stream discharge for each year of the analysis^[3]. The cumulative annual discharge data did not correspond to a normal distribution. In addition, the normal distribution was skewed to the left, meaning that more years would be classified as dry years (29 in total) than wet years. Thirty-eight years (38) out of sixty-eight (68) were below the average with a normal distribution. This is due to the very high cumulative river discharge

values of the very wet years, resulting in an asymmetry in the data.) The number of years classified as dry years was 29, 17 years as average years, 14 years as wet years and 8 years as very wet years.

Seasonal scale

The objective of the seasonal analysis of the discharge in the upper Senegal River basin was to detect any trends, or lack thereof, that might occur within the climate classification. In the seasonal analysis, the cumulative mean seasonal discharge volume was used. Thus, the high water period had the highest discharge. In order to better understand the evolution of the seasonal discharge for each climate classification, a percentage of the average analysis was performed for each season in each climate classification. It is clear from this analysis that the seasonal discharges in the high water period show the greatest variation. Note that all seasons in the dry (and sometimes even average) climate classification were below 100. This is due to the large discharge volumes in wet and very wet years, which bias the average value towards higher discharges. The importance of this finding lies in the possibility of creating more accurate seasonal discharge simulations. The simulations can consist of estimating missing data from previous years or making future seasonal forecasts. Due to the variability of precipitation in each season, future seasonal precipitation should be forecast rather than annual forecasts^[3].

The concordance of the classifications of very wet and wet years of discharges and the evolution of rainfall is in line with the work of Sow^[7] and Faye^[26] who

highlighted the abundance of rainfall in the 1950s and 1960s. Similarly, the importance of the dry years noted in this study confirms the work of Sow ^[7] and Faye *et al.* ^[10] in the Senegal River basin and Faye and Mendy ^[27] in the Gambia River basin. The hydrological deficits indicated are therefore in the same magnitude as those obtained by several authors who have conducted hydrological studies, either in the same catchment or in other basins in Senegal, or in Africa. For example, the work of Kouassi *et al.* ^[29] in the Bandama catchment indicates hydrological deficits of -16.32% for mean rainfall, -31.49% for effective rainfall, -59.94% for discharge potential and -15.17% for infiltration potential. Studies carried out in Africa by Sighomnou ^[30] and Goula *et al.* ^[31] have highlighted the hydrological deficits following the decrease in rainfall.

The return to rainfall noted in the 2000s and coinciding with the classification of wet years in terms of discharge is also in line with the work of Ali and Lebel ^[32] on the Sahelian zone, Ouoba ^[33] on Burkina Faso, Ozer, *et al.* ^[34] on Niger and Faye ^[35] on Senegal, which indicated the improvement in rainfall conditions since the 2000s, with its corollary of increased discharge. Thus, beyond the drought of the 1970s, this new hydrological change occurred again in the mid-1990s and is marked by an increase in river discharges. This similarity between the variations in climatic conditions and the hydrological response of the basins would therefore be on a global scale ^[36].

Based on the seasonal analysis of this study, it was determined that the volume of high season flows is the highest for each climate classification. This corresponds to the flooding phenomena noted in the valley. Devastating floods occur due to heavy rainfall in many parts of the basin. Studies have shown that the Senegal River basin is prone to frequent floods and droughts due to the high interannual variability of rainfall ^[37]; the most devastating effects of these extreme events, especially floods, are the washing away of agricultural land, affecting agricultural production and food security, destruction of homes, increased health risks and the spread of infectious diseases ^[38].

6. Conclusions

Through the annual analysis of the discharge of the upper Senegal River basin, the years have been classified into five categories. This study focused on the annual classification and the seasonal study of the flow of the upper Senegal River basin. The annual classification and seasonal analysis involved the collection of historical daily flow data (from 1950 to 2018) from the OMVS. These data were converted to volume flowed, then summed into annual cumulative volume data, and corresponded to a

lognormal distribution. The mean and standard deviation were then calculated and manipulated to determine the climatic classification ranges of the flow rates. Each year was classified as very humid, humid, medium, dry or very dry. The years in the classifications were then analyzed. A seasonal analysis was then performed and the annual data was divided into two periods (the high water period and the low water period). The cumulative volume for each season of each year was then calculated. Then, the seasonal average volume flow for each classification was calculated and analyzed. Trends were observed and noted, and additional analyzes, such as the percent of mean and percent of total runoff volume, were performed each season.

It was found that the seasons of the high water period had the highest flow, regardless of their climatic classification. It was also found that the period of high water was the one with the most variability and that it influenced the classification by providing large volumes of flows. The months of the high water period had some of the highest flow volume values. This could be because the more rainier the year, the longer the runoff during the low water period will last and the more groundwater will be stored and contribute to the flow of the stream. The data were then compared to the evolution of precipitation data in the Senegal area. Strong correlations were established from these comparisons and it was noted that it is possible to relate the annual classifications of the basin's flow volume to the variability of precipitation. However, it is necessary to proceed to annual classifications of precipitation in the Senegal area to better represent them. This study presented the results of the flow analysis of the upper Senegal River basin. To deepen this work for future work, the following are suggested: A more in-depth analysis of precipitation in the Senegal River basin and its comparison with the flow analysis of the present study; A study of groundwater storage and its effects on runoff and stream flow. Such studies could be beneficial for flood forecasting, because the more information we have about seasonal and climate change in flow, the more accurately it will be possible to predict stream flow.

Many adaptation strategies for the agricultural sector and water demand in the face of declining water resources can be noted: the adoption of short-cycle crops, the abandonment of certain crops and the introduction of new crops. The first spontaneous adaptation consists in adjusting the cropping calendar to the climatic conditions of the year. Currently, the trend is to abandon long-cycle speculations that no longer respond to the climatic context. Also, farmers practice the intercropping system to mitigate the risk of low yield. In addition, they are

obliged to modify their agricultural calendar as well as the cultivation technique, to practice multiple sowing, dry or late, and to reduce their sowing.

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ARTICLE

The Differences between County, County-level City and Municipal Districts in the System of Administrative Divisions in China

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ABSTRACT

The administrative division is an important means of political power reorganization and management, resource integration and optimal allocation, which profoundly shapes the spatial layout of urban development in China. To clarify and compare differences between counties, county-level cities and municipal districts is the primary premise for the study of administrative division and urban development. This paper analyzes the institutional differences between counties and county-level cities, as well as counties, county-level cities and municipal districts, from the aspects of organizational structure, urban construction planning, land management, finance, taxation and public services. The research shows that the establishment of counties, county-level cities and municipal districts adapt to different levels and stages of economic and social development, and the conversion from county to county-level city and the conversion from the county (or county-level city) to the municipal district are both important transformation ways to change their administrative systems, which has different management system and operation pattern. At the same time, the transformation of the county-level administrative region is also a "double-edged sword", we should think about the administrative system as a whole to decide whether it should be adjusted, and effectively respond to the actual needs of local economic and social development.

1. Introduction

As a country with the largest population and the second-largest economy in the world, China's urbanization has had a profound impact on the world's political and economic patterns. However, the current understanding of the regularity of urbanization in China is relatively

insufficient, especially the understanding of the key role of administrative divisions in the process of urbanization in China is still limited. The administrative division is an important part of the construction of state power in China and the basic institutional framework of the CPC's governance. The scientific and reasonable establishment

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of an administrative region is closely related to economic development and social stability, and is very meaningful to China's transformation and development. The county is the basic unit of the national management structure, a key link between the high-level administrative regions and grass-roots management, is an important basis for developing the economy, ensuring people's livelihood, maintaining stability and promoting the country's long-term stability^[1]. Since the reform and opening up in 1978, administrative division adjustments such as conversion from county to county-level city, conversion from county (or county-level city) to municipal district, and the merger of the municipal districts and counties have been very frequent. The number of municipal districts increased from 408 to 970, the number of county-level cities increased from 92 to 375, but the number of counties decreased from 2011 to 1335 from 1978 to 2018. However, the research on the system differences between counties, county-level cities and municipal districts is still insufficient. Many people do not know the differences between them. Therefore, it is of great significance to strengthen the research on the system differences of county-level administrative regions, which help to understand China's urbanization process and the changes in an administrative management system.

There are great differences between Chinese and foreign administrative systems. In western countries with a highly mature market economy, administrative regions are mostly formed naturally with economic and social development, and are rarely adjusted by administrative forces. There are few theoretical and practical studies on the adjustment of administrative divisions abroad. As the urbanization level has reached 63.89% in 2020, the issue of administrative division in metropolitan areas has become the focus of relevant research^[2-4] and local government management has also attracted attention^[5,6]. However, due to the strong economic and planning authority of governments at all levels in China the administrative division has become an important force to promote regional economic development, which is directly related to the improvement of administrative management efficiency and urbanization quality, and has a profound institutional constraint on an urban spatial structure. The research of administrative division started relatively late in China, but the related research has been deepened and carried out in the exploration of different disciplines, and gradually become the hot spot of current research. The research mainly focuses on the institutional change of administrative regions, administrative division adjustment effect, reform program, and the relationship between adjustment of administrative division and urbanization,

regional economic development, and administrative system reform^[7-16]. China implements a hierarchical city management system, including municipalities directly under the central government, cities with municipal districts and county-level cities, with higher-level cities getting more resources easily. The jurisdiction of the city is wide, including both built-up areas and surrounding rural areas. Deepening the understanding of the differences between county-level administrative regions is an urgent need to master the internal logic of urbanization in China.

There are great differences between Chinese and foreign administrative management systems. There is a lack of practical and theoretical research on the adjustment of administrative division abroad, and there are relatively few studies on the differences between counties, county-level cities and municipal districts. The research on the institutional differences between counties, county-level cities and municipal districts is relatively weak in China. Therefore, on the basis of literature and field investigation, this study discusses the system differences between counties, county-level cities and municipal districts, which are the most basic in the study of administrative division, and provides a reference for further theoretical and practical research.

2. Basic Connotation of Counties, County-level Cities and Municipal Districts

2.1 The Basic Concept

County has a long history in China. Shire and County System is a system of local administration which took shape during the Spring and Autumn Period and the Qin Dynasty^[17]. The county system has been used until now and is still a grass-roots administrative region in China. It used to be the residence of the ancient emperor originally, namely "Wang Ji" (it means capital), known as "red county"^[18]. In the late Spring and Autumn periods, counties became local administrative units, which were directly under the direct jurisdiction of the central government. Their governors can be replaced at any time or at regular intervals, and their management scope is usually artificially delimited, with sub-county organizations such townships^[19]. Adapted to the rural socioeconomic conditions, counties are the crucial institutional unit to manage rural regions. It is the "longest-lived" form of regime organization in China and is known as the most successful system design of China's grassroots regime^[18].

The county-level city is a hybrid institutional system between city and county, which combines urban

management with rural management ^[20], not only emphasizing city construction and management but also taking villages into account at the same time. In 1921, the law of “System of Municipal Autonomy,” the national legislation on the institution of the city, was promulgated by the central government for the first time, thereby marking the official birth of China’s urban system. Nevertheless, the designation of the county-level city did not appear until 1983. At the beginning of the People’s Republic of China, the local city was administered by the subprovincial administrative region at first, which was converted into a prefecture in 1970. Eventually, the name was changed into a county-level city in 1983 when the reform of the prefecture-level administrative region was executed. County-level cities are the products of the fast growth of township industries, the rapid advancement of urbanization, quick changes in the industrial structure, and the speedy transition of the residential space. The county-level city is a small city normally, which is a hybrid administrative region integrating the functions of regional administrative region and urban administrative region.

A municipal district refers to an urbanized area under the jurisdiction of prefecture-level cities. The administrative level of a municipal district is usually equivalent to a county, mainly to share the urban management function of a prefecture-level city government. In another case, the level of a municipal district is higher if it is under the jurisdiction of a municipality, which is equivalent to an autonomous prefecture or prefecture-level city ^[21]. The establishment of municipal districts is the inevitable outcome of the development of modern cities and urbanization to a certain scale. At this time, the complexity of urban internal organizations will increase exponentially, causing great pressure on the central urban areas, therefore, urban management can be better strengthened by establishing several municipal districts. However, the municipal district was not legally established to be a form of local administrative institution until 1954 when the Constitution of the People’s Republic of China released the statement that “municipalities and larger cities should be Compared with the county system and city system, the municipal district system appeared the latest. In the same year, the Organizational Law of the National People’s Congress and People’s Government of PRC at Various Levels stipulated that “the people’s government of municipal districts and cities without districts, at the approval of the higher-level government, has the power to set up a certain number of sub-district offices as its agencies when necessary.” This demonstrates that the municipal district is the agency of the municipal government and a kind of administrative unit of the urban administrative district.

The efficiency of urban management can be improved by establishing several sub-district offices, which are the basic administrative region and agencies of the local government such as municipal districts or cities. It includes several community residents’ committees or a few administrative villages. The municipal district has a comparatively strong dependence on cities, it is an important part of the city. Municipal districts directly handle social public affairs, which is related to the supply of public services and urban operation efficiency, which directly affects the improvement of urbanization quality.

2.2 The Differences in Approval Authority for Different County-level Administrative Region

In terms of the authority of establishing municipal districts, counties and county-level cities are mostly directly determined by the central government. “Any addition, cancellation of administrative region name, change of administrative region name and boundary of the administrative region at or above the county level, such as counties, county-level cities, shall be implemented with the approval of the Central People’s Government ^{① ②}.” In comparison, since the founding of the People’s Republic of China, the power of approving the establishment of municipal districts has been transferred from the prefecture-level cities’ government first to the provincial government and then upward to the central government. In the early period of the founding of the People’s Republic of China, the number and size of municipal districts in large and medium-sized cities were decided by each city without the approval of the central government, which led to the large difference in the number and size of municipal districts in different cities. In 1955, the law of the Decision of the State Council on the Establishment of Cities and Towns was enacted, stating that “the suburb of cities should not be too big,” and that “the establishment of municipal districts should be controlled within a proper number” and also “the establishment and alteration of the institution of municipal districts or towns are decided by the Provincial People’s Council.” Since then, the provincial government has become the subject of approving the establishment of municipal districts. After the reform and opening up, the power to approve the adjustment of administrative divisions at or above the county level was delivered to the State Council. For the sake of the conservation

① Provisions of Ministry of Internal Affairs on the Authority over the Unified Change of Administrative Division.

② Instructions of Ministry of Internal Affairs on the Change of Administrative Units above County Level to be Submitted to the Central Government for Review and Approval.

of cultivated lands, in 1997, the Central Committee of the Chinese Communist Party, in conjunction with the State Council, issued the law of "Notification on Further Strengthening of Land Management and Cultivated Land Protection," which required that "the review and approval of conversion from county to county-level city are suspended since the promulgation of this law", and the establishment the county-level city entered the stage of strict control. Since the policy of conversion from county to county-level city has been suspended for a long time, local governments have mostly shifted the focus to transforming counties (county-level cities) into districts. In 2002, The State Council decided to suspend the establishment of municipal districts for some time to control the excessive and chaotic situation in a few regions. Since 2013, with the continuous improvement of the urbanization level, the work of conversion from a county (or county-level city) to a municipal district gets resumed successively.

In recent years, along with the reform of Enhancing Jurisdiction and Strengthening County, the actual administrative power of certain counties and county-level cities is reinforced in some regions, which is the same trend for municipal districts. In many regions, the power of municipal districts has been continuously strengthened with socioeconomic development, and the difference between the county, county-level city and municipal districts has been very not very clear^[22]. In the era of a planned economy, relatively small power was granted to municipal districts and of weak independence, with its economic management and the handling of economic business of subdistricts being in full charge of the city departments. Existing as working agencies, municipal districts undertake part of urban management functions and play a pivotal role in organization and coordination. However, after the reform and opening up, cities like Nanjing, Guangzhou, Xi'an, Lanzhou, Taiyuan, Harbin and other prefecture-level cities took the lead to delegate power to the municipal districts, initiating the exploration of the reform of municipal districts. There were five aspects to decentralization, including the financial power, the construction right of commercial and service industries, certain power of city development and construction, the management authority such as sanitation and greening and other management power, such as the decentralization of middle school management, urban personnel cadres, the establishment of institutions.

3. Institutional Differences between Counties and County-level Cities

In China, the role of urban planning is to understand the future of the city, while the role of the administrative

division is to understand the reality of one region. Administrative division adjustment has a profound impact on urban development, which is primarily displayed in land development policy, urban and rural planning, urban construction system, financial system, household registration system, real estate policy, education and medical facilities. Therefore, this study mainly compares the institutional differences between county-level administrative regions from five aspects: organizational system, urban construction planning system, land management system, fiscal and tax financial system and public service system. The five aspects are elaborated as follows.

3.1 Organizational Structure System

There are obvious differences in the organizational structure among county-level administrative regions. Compared with counties, county-level cities are entitled to establish more institutions and arrange more leading posts and personnel. Usually, the candidates for the Secretary of the Communist Party Committee of county-level cities are easier to become a leader at a higher-level administrative rank compared with their counterparts of counties. A lot of them can be admitted into the Standing Committee to enjoy a political treatment at the vice-prefecture level, which also makes it easier to get close to higher levels of government and promotion. In terms of personnel appointment and removal, some provincial (autonomous region) governments have direct supervision and control over the personnel of county-level cities, and county-level cities can set and replenish the number of public security and judicial personnel. The county-level city can set up sub-district offices, which can bring the residents in the rural-urban fringe into the urban community management, effectively resolving the contradiction caused by the coexistence of county government and township government. Moreover, county-level cities were also chosen as the main areas for institutional reform.

3.2 Urban Planning System

In terms of urban construction, county-level cities have more independent space than counties. The overall urban plan of a county must be implemented only after the approval of the prefecture-level city (prefecture or autonomous prefecture) government, while the overall urban plan of a county-level city can be approved by the provincial (autonomous region) people's government. Besides, county-level cities are offered more support from higher-level governments for urban construction, such as urban reconstruction and management, electricity

quota distribution, and construction of electric power facilities. In contrast, the support for counties is more of poverty alleviation and agricultural subsidies. For example, in 2016, the subsidies in Zhanyi County of Yunnan province mainly included subsidies for converting farmland to forest, central agricultural protection support subsidies, grassland ecological protection subsidies, animal husbandry and high-quality seed subsidies, agricultural machinery purchase subsidies and forest ecological benefits subsidies. Compared with counties and municipal districts, county-level cities can usually enjoy more favorable national policies. Take Wenshan County in Yunnan province as an example. As far as the project establishment of economic construction was concerned, Wenshan County can only examine and approve construction projects of less than 1 million dollars. However, when Wenshan county was converted to a county-level city, the grant increased to 30 million dollars, that is, 30 times more than the county, which shows the great difference between county and county-level cities. County-level cities shall be given priority when applying for a superior fund supporting projects and important urban infrastructure construction projects. Furthermore, the implementation of nationally relaxed policies typically starts with county-level-cities and later extends to counties. When assigning certain projects, the province (or autonomous prefecture) only considers county-level cities. For example, county-level cities can participate in and strive for the title of "National Sanitary City", and the evaluation criteria clearly state that "this standard applies to all cities and districts of municipalities", with counties being outside of consideration.

3.3 Land Management System

The third difference between the county and county-level city lies in the land management system. Compared with city lies, county-level cities have more independent power and easier access to preferential policies and financial support in construction project approval and infrastructure investment. Besides, the allocation of land use for construction and the permission of transforming agricultural land into nonagricultural land are more than those of counties. Moreover, they can independently determine the collection and tax rate of urban construction and maintenance tax, and have the right to approve large areas of land. For example, before the establishment of Puning city in Guangdong Province in 1993, an average of 0.51 km² of non-agricultural construction land was examined and approved annually during 1989-1992. However, after the establishment of Puning city in 1993, an average of 1.05 km² of construction land was

requisitioned and approved annually during 1993-1998. The number of land indicators increased greatly. Another example is Handan City (a prefecture-level city). In 2016, among all its newly increased land, the annual average figure for county-level cities was 0.76 km², counties 0.40 km², and the municipal districts 0.19 km², indicating that the land index of the county-level city is higher. At present, land transfer income and transfer payments have become the main financial sources of most county-level governments. More construction land indicators mean more land income. The lack of construction land indicators not only affects land transfer income, but also has a great impact on the landing of investment items and land mortgage loans.

3.4 Fiscal, Taxation and Financial System

The fourth difference between the county and the county-level city lies in the fiscal and financial system. County-level cities have more advantages in provincial finance sharing and can obtain more financial working capital, while the provincial financial appropriation of counties is prone to be intercepted by prefecture-level cities. In addition, conversion from county to county-level city would raise the urban maintenance and construction tax from 5% to 7%, putting more pressure on local enterprises. Concomitantly, the proportion of financial rebates will increase, but transfer payments and special support funds of counties can only be used in agriculture-related fields, while county-level cities can be used in urban construction fields. After the conversion from county to county-level city, the increase in the number of institution establishments and the cost of urban construction will exacerbate the financial pressure to varying degrees. The financial business of counties concentrates on credit business, with rural finance accounting for a relatively large proportion. Finance, customs and other vertical management departments are very important to the development of the county economy, but the administrative authority of this part is still mainly concentrated in the superior cities. On the other hand, county-level cities have obvious mixed characteristics of urban and rural finance and wider business scope. They have obvious advantages in setting up financial institutions and credit approval authority. They can have certain foreign exchange quotas and allow the establishment of bank branches, so they can act as investment guaranty or issue loans with large quotas. In addition, county-level cities can also set up customs to handle entry and exit procedures and directly manage the approval and issuance of license plates and driving certificates.

3.5 Public Service System

The fifth difference between the county and county-level city lies in the public service system. Compared with counties, county-level cities have strengthened their power in the field of public services, paying more attention to the urban road, communication and other infrastructure construction, and can set up high-grade hospitals. Moreover, county-level cities can gain more industrial projects, land allocation, and water resources. They can also directly apply for subsidies for sewage disposal plants and waste treatment plants from higher-level governments and can be granted more capital and quotas for low-income housing. However, after the county is converted to a county-level city, the corresponding educational funds will be reduced and the local finance should bear more.

4. Institutional Differences among Counties, County-level Cities and Municipal Districts

In China's county-level administrative region system, counties and county-level cities have a relatively complete and independent administrative management structure, which manages political, economic and social affairs within their jurisdiction. In contrast, municipal districts are an organic component of prefecture-level cities, and their management is highly centralized, which is quite different from counties and county-level cities. In other words, municipal districts are incomplete governments, which are under the unified management and regulation of prefecture-level cities in many aspects. Tables 1 and 2 elaborate on the specific differences.

4.1 Organizational Structure System

Regarding the organizational structure system, the distinction is demonstrated as follows (Table 1).

(1) The first aspect is related to the correlation with prefecture-level cities. Under the system that cities take charge of counties, prefecture-level cities are the higher-level authority of both counties and municipal districts. According to the Constitution, prefecture-level cities are not permitted to establish county-level cities, and the legitimate higher-level authority of county-level cities is the government of the province or autonomous regions. Prefecture-level cities administer counties and municipal districts, but act as the representing government of county-level cities.

(2) For the administrative level, after conversion to municipal districts, counties and county-level cities in

prefecture-level cities are still at the division-head level^③. Counties in municipalities will rise from the deputy-bureau-director level to the bureau-director level.

Table 1. The institutional difference among counties, county-level cities and municipal districts

Items	County	County-level city	Municipal district
Administrative level (prefecture-level cities)	division level	division level	division level
Administrative level (sub-provincial-level cities)	division level	division level	deputy-bureau-director level
Administrative level (municipalities)	deputy-bureau-director level	not included	bureau-director level
Authority to govern subdistricts	generally not	yes	yes
Independence of functional departments	relatively strong	strong	weak
Regional economic development	give priorities to villages and take cities into account as well (primary industry)	give priorities to cities and take villages into account as well (secondary industry)	give priorities to cities and take villages into account as well (tertiary industry)
Finance and tax	relatively independent	independent	not independent
Proportion of finance and tax	relatively low	low	high
Proportion of transfer payment from higher-level governments	relatively high	high	low
Department of public security and fire prevention	independent	independent	not independent
Court and procuratorate	independent	independent	independent
Urban construction planning	relatively independent	independent	not independent
Land management	relatively independent	independent	not independent
Social security	relatively independent	independent	not independent

(3) Regarding organization establishment, counties and county-level cities have a relatively complete responsibility system. In contrast, departments of municipal districts related to finance, foreign exchange, customs, taxation, and national security are administered by the central government, whereas other organs pertaining to fiscal service, planning, national territory, urban management, municipal administration, public security, procuratorates, and courts are all agencies of corresponding departments,

^③ Opinions on some problems of sub provincial cities.

thus are under direct administration of prefecture-level cities. Moreover, departments related to industry and commerce administration, environment conservation, quality inspection, food and drug administration are also under the direct charge of prefecture-level cities. All vertical departments are accountable to those at higher-level in a systematic manner, where governments of prefecture-level cities have no rights to administer and find it hard to coordinate. In comparison with municipal districts, counties and county-level cities possess greater independent administrative power with a relatively complete responsibility system and establish many agriculture-related departments based on the elaborate division of work. Taking Ruyang County in Central China as an example, There are a considerable number of agricultural regulation departments, including the Bureau of Agriculture, Bureau of Animal Husbandry, Forestry Administration, Bureau of Water Resources, Administration of Grain, Agriculture Comprehensive Development Office, Economic Forest Office, Immigration Office, Poverty Alleviation and Development Office, Agricultural Machinery General Station and other agriculture-related management departments. Most of the departments directly managed by municipal districts are usually service-oriented functional departments. After the transformation of counties (county-level cities) into municipal districts, the power of land, finance, planning and construction will be concentrated in prefecture-level cities. Generally speaking, the total number of institutions will be appropriately increased after the transformation of counties (county-level cities) in cities above the deputy provincial level. Taking Wenjiang County of Chengdu as an example, following the transformation, the number of departments comprising the committee increased from 6 to 7, and the number of those comprising the government increased from 19 to 23.

(4) The fourth is regarding personnel quota distribution. The organization of counties (cities) under the jurisdiction of prefecture-level cities and sub-provincial cities shall be independently approved by the central government. Nonetheless, when these counties (county-level cities) are converted into municipal districts, the organizational establishment and personnel quota are decided by their higher-level authority. Therefore, the quota shortage can be addressed through internal adjustment of the city. The changes of quotas for certain urban administration or agricultural departments are permitted, but the total amount is generally unchanged. Compared with the county (county-level city), the institutional setting of municipal districts is generally tight, and the number of personnel is also far behind the county (county-level city). Counties

(county-level cities) administered by municipalities are granted more quotas of certain organizations when transformed into municipal districts to increase the establishment of municipal departments dispatched agencies. The functions and authority of municipal districts lack clear legal provisions, and are mostly decided by the prefecture-level municipal governments themselves, often based on the views and understanding of the main leaders of prefecture-level cities, showing different characteristics and distinct personal styles in different periods. Moreover, as municipal districts and cities divided into municipal districts are geographically overlapped, the overlapping of responsibility is also prevalent.

(5) Based on the existing laws, counties cannot set up sub-district offices, while county-level cities and municipal districts can do it, resulting in low administrative efficiency due to overlapping between vertical county departments and town government agencies in many towns where the county government is located.

4.2 Urban Planning System

Regarding urban construction planning, the following aspects reflect the differences between counties (county-level cities) and municipal districts. First, the county government has the power to formulate county seat planning and common town planning. The government of county-level cities has the power to formulate urban planning for the whole region. In contrast, the government of municipal districts has no authority in this respect. Article 3 of the Law on Urban Planning stipulates that “cities mentioned in this law refer to municipalities, cities or towns established by the State according to an administrative institution.” Besides, Article 12 stipulates that “the city government is responsible to organize and formulate urban planning. Planning of the town where the county government is located is in the charge of the county government.” However, the planning authority of municipal districts is uniformly performed by the Bureau of Planning of the city. Meanwhile, power concerning urban road planning, fire prevention and control, water resources management, greenery coverage, and environmental protection are carried out by the city government as well. Second, counties and county-level cities are generally responsible for the compilation and approval of urban and rural planning, and urban construction funds are mostly self-raised. However, the urban planning of municipal districts is generally carried out uniformly by the prefecture-level city, and the relevant departments of the municipal district only play a coordinating role. As stipulated in Article 18 of the

Table 2. the distinction of economic and social administrative authority between counties (county-level cities) and municipal districts ^[10]

	Items	District government under municipalities	District government under municipalities	County-level governments
Economic development	policies and planning formulation	√		√
	development zones	√	√	√
	state-owned enterprises			√
Public security	public security		√	√
	fire prevention			√
	rescue and disaster prevention		√	√
Health care	The first-level, second-level and third-level health care	√	√	√
	ambulance service	√		√
Education	elementary education	√	√	√
	secondary education	√	√	√
	higher education			
Social security	old-age pension	√		√
	Unemployment insurance	√		√
	work-related injury insurance	√		√
	medical insurance	√		√
Social welfare	Institutional rescue	√		√
	Pension for parents supported by a single child	√		√
	Pension for soldier's family	√	√	√
Social rescue	job training	√	√	√
	basic welfare	√	√	√
	low-rent housing	√	√	√
Cultural and entertainment facilities		√	√	√
Electricity and gas supply	electricity generation			√
	electricity supply			√
	gas supply			√
Transport facilities	roads and bridges			√
	urban roads and bridges	√	√	√
	parking facility	√	√	√
	roadway lighting	√	√	√
	public transport service	√		√
	traffic regulation	√		√
	airport			
	port and harbor			√
Communication facilities	postal service	√		
	telecommunication			√
	broadcasting television			√
Environment infrastructure	tap water production			√
	tap water supply			√
	sewage collection			√
	sewage treatment			√
	drainage and flood control			√
	water conservancy			√
	solid waste collection	√	√	√
	solid waste disposal			√
	road cleaning	√	√	√
Environment protection	environment planning			√
	environment implementation	√	√	√
	pollution detection		√	√

Urban Planning Law, “large and medium-sized cities, on the basis of overall planning, have the right to carry out planning by municipal districts so as to further control and confirm the purpose, boundary, and capacity of different land lots as well as to coordinate the construction of basic and public facilities.” Similarly, Article 21 stipulates that “municipal district planning is reviewed and approved by people’s government of the prefecture-level city.” Specifically, the staging plan may be jointly prepared by the prefecture-level city and the municipal district, but reviewed and approved by the prefecture-level city government. In addition, the regulatory plan and site plan are typically drafted by the municipal district, then reported to the Bureau of Planning of the prefecture-level city for recording and filing, and it is finally implemented by the municipal district government. Under the supervision of both the Bureau of Planning and the district government, the regulatory plan of bordering areas is made through negotiation between the city and municipal district ^[23].

4.3 Land Management System

As far as the land management system is concerned, the distinctions are illustrated as follows. First, the Bureau of Planning of municipal districts is the agency led by the prefecture-level city so the city government controls the power of land expropriation, supply, and approval. While, the people’s governments of cities and counties are in a principal position in terms of land supply ^④, they are independently responsible for land acquisition, supply and approval of counties and county-level cities. Second, the allocation of land use for the construction of both counties and municipal districts is determined by the city divided into districts, but the compensation standard of construction land requisition of the municipal district is often higher than that of the county. Third, compared with municipal districts, county-level cities and counties also have obvious advantages in land approval and credit support. Forth, in comparison with municipal districts, counties and county-level cities have the noticeable advantage in land use approval and credit support, as it is stated in the existing law that “the sale of land-use rights is conducted by people’s government of cities and counties in accordance with plans and procedures” ^⑤,

and that “the approval power of existing land use for construction within allowed areas belongs to people’s governments of cities and counties, so does the land returns” ^⑥. This indicates that the power of municipal districts to approve the sale of state land-use rights and the power of construction and planning are both transferred to the city government; therefore, it is obligatory to uphold the unified regulation over land by the prefecture-level city government. As stated in the law, “the land used to establish approved industrial parks, science parks, and development zones in municipal districts must be incorporated into the unified regulation and supply of the city.” ^⑦

4.4 Fiscal, Taxation and Financial System

Regarding the fiscal and financial systems, differences are demonstrated in the following aspects. First, counties and county-level cities are mostly first-level financial institutions with independent accounts. Financial fund settlement and dispatching can be directly conducted in the province, while municipal districts generally do not have independent financial accounts (except for some newly established municipal districts). Accordingly, the finance cannot be connected directly to the province, instead the finances are connected to the prefecture-level city and then to the province. Therefore, counties and county-level cities but not municipal districts are entitled to receive the transfer payment from higher-level authorities. Second, based on the division of budgetary level of revenue according to the location of enterprises, cities (municipalities excluded) implement a financial system based on “the division of increased revenue” in counties (county-level cities), but “the proportional sharing” in municipal districts. Conversely, a low proportion of financial sharing affects the increase in public service in municipal districts, which is predominantly evident in cities with small-scale finance in the central and western parts of China. Third, the incentive for gaining extra revenue and mechanism for the transfer payment is also different between counties (county-level cities) and municipal districts. Fourth, the statistical criteria are also different. The general budgetary revenue of counties (county-level cities) comprise taxes turned over to the state, fixed revenue, shared revenue

④ Notification of the Ministry of Land and Resources on the Serious Implementation of ‘Opinions of the State Council on Solving Housing Difficulties of Urban Low-income Families’ and Further Strengthening Regulations of Land Supply.

⑤ Law of the People’s Republic of China on the Administration of Urban Real Estate.

⑥ Opinions of the Ministry of Land and Resources on Some Problems of the Implementation of ‘Administrative law of the People’s Republic of China’ and ‘the Regulations on the Implementation of the Land Administration Law of the People’s Republic of China’.

⑦ Notification of the State Council on Strengthening the Management of State - owned Land Assets.

with the city, and the portion of special shared revenue. In comparison, the general budgetary revenue of municipal districts comprises taxes turned over to the state, shared revenue from prefecture-level city, fixed revenue from municipal districts, shared revenue from municipal districts, and special funds allocation.

4.5 Public Service System

Regarding the public service system, the differences are illustrated in the following aspects. First, the social security criteria of municipal districts are typically higher than that of counties and county-level cities. Second, the threshold for the free migration of household registration between municipal districts is lower. Besides, most counties and county-level cities tend to be more independent and have their own television station, broadcasting station, and comprehensive newspapers, whereas the broadcasting television signals of municipal districts are uniformly covered by the prefecture-level city and their cultural and sporting facilities are more attached to prefecture-level cities. With respect to the teaching staff and expenditure guarantee, municipal districts are generally stronger than counties and county-level cities. In municipal districts, high schools are uniformly managed by the city, whereas middle and primary schools are managed by the Education Bureau of the municipal districts. Nevertheless, middle and high schools are regulated on their own in counties and county-level cities while the central school of the town regulates the ordinary rural primary schools. Moreover, the Public Security Bureau in counties and county-level cities have the power and duty of traffic regulation but the Public Security Sub-Bureau in municipal districts does not. Finally, the price set under the government's guidance can be designated by counties and county-level cities for local areas, as stated by Article 20 of the Pricing Law of the People's Republic of China, "based on the authorization of the people's government of the provinces, autonomous regions and municipalities, the people's government of cities and counties has the power to determine the price set by the government or set under its guidance in accordance with the pricing authority and specific applicable scope prescribed in the local pricing catalog."

5. The Logic Analysis and Thought on Advantages and Disadvantages Underlying Conversion from Counties to County-level Cities and Counties (County-level Cities) into Municipal Districts

Through the above analysis, we can see that counties

prioritize rural management, which is more favorable for the development of the primary industry. China was in an agricultural society for a long time until 100 years ago. This is also the main reason why the county has remained for more than 2000 years. County-level cities have emerged with industrialization and urbanization, and they have only a hundred years of history in China. They emphasize more on urban construction and management and, at the same time, take rural work into account, thereby creating more beneficial conditions for the development of the secondary industry. Municipal cities emerged after the founding of the people's Republic of China in order to facilitate urban management, they mainly focus on urban management, public service and social construction, and have more advantages in serving the development of tertiary industry. In a word, counties are more prominent in agricultural management, whereas county-level cities are more remarkable in economic management primarily because of the reinforced power in planning and construction, land development, and fiscal management. Alternatively, municipal districts have a more salient role in social administration because of strong regional connectivity and weaker independence compared with county and county-level cities.

5.1 The Power Change after the Change from County or County-level City to Municipal District

Generally speaking, counties and county-level cities have the following advantages of administrative authority in addition to the economic and social administrative authority of municipal districts. In terms of economic development and public security, county (county-level city) governments can independently decide on economic development policies and plans, formulate environmental protection plans and manage state-owned enterprises, and directly take charge of fire safety and ambulance services. With regard to coal power and communication facilities, governments of counties and county-level cities have direct control over the supply of electricity and gas, as well as basic communication facilities like telecommunication and broadcasting televisions. Regarding personnel resources and social security, the professional ranks and titles are decided by counties and county-level cities themselves; for municipal districts, however, it is up to the prefecture-level cities and difficult to be conferred. Furthermore, governments of counties and county-level cities directly handle work about unemployment insurance, work-related injury insurance, old-age pension, and support for old people who are supported by single-child and institutional subsidies and rescue. Regarding transport infrastructure, governments of counties and county-level

cities are accountable for the construction, regulation, and service of roads, bridges, public transport, ports, and harbors. Both the municipal districts and counties (county-level cities) have their own independent public transport system in that urban public transport and coal power facilities are typically trans-regional, which require unified planning and regulation of the city. Following the conversion from counties to county-level cities, the power in urban construction and planning, land development, taxation, and finance will be reinforced considerably, which is more advantageous to urban planning, construction, and management, and easier to improve the popularity of the city and quality of urbanization. Hence, more investment will be attracted and the urban function, governance capability, and public service functions will also be enhanced. Thus, counties are more willing to be county-level cities.

Most central cities are keen on embracing the conversion from counties (county-level cities) to municipal districts, as it expands the urban financial power and land reserves, but counties (county-level cities) have attitude. The part reason is that counties and county-level cities can obtain funds and policy support from both the provincial government and prefecture-level city government, whereas municipal districts can rarely obtain provincial-level assistance and support, as it is dependent on the urban financial capability. Conversely, after the administrative division adjustment, the investment attraction, industrial distribution, and infrastructure construction will be considered comprehensively by the prefecture-level city. Besides, the public service and welfare benefits of the government will be upgraded from the previous county level to the prefecture-city level. However, as far as the financial system is concerned, after the administrative division adjustment, the municipal district faces some variations like a higher proportion of fiscal revenue turned over but 50% lower provincial transfer payment and the cancellation of general transfer payment. To add to this, remuneration and welfare expenses have to keep up with the level of the central city, thereby leading to decreased fiscal revenues but increased expenditures for some municipal districts. Consequently, the mismatching between financial ability and administration responsibility typically emerges in the newly established municipal districts owing to declining fiscal capability, deprived special subsidies, but mounting social administration affairs. For instance, as the previous Public Security Bureau of the county (county-level city) is shifted into the Public Security Sub-Bureau of the district, the urban Public Security Bureau and Commission of Headcount Management will decide the personnel quota, but the district assumes the remuneration. For another example,

the planning and approval of the power of petrol stations belong to departments directly under the city government, but the safety responsibility of the workplace is assigned to the district. Moreover, because of the weak economic base, some municipal districts in underdeveloped areas of the central and western parts of China have a much weaker practical administrative power compared with counties, despite the same level. A disparity of political status between leading officials working in municipal districts and counties (county-level cities) also exists; the former generally feel less appreciated, harder to get promoted, and are unable to match their counterparts in terms of power.

After transformation, previous finance will be lowered from the independent first-tier level down to the financial branch of the central city, relying heavily on urban support. If the urban finance is relatively weak to meet the local expense, it will limit the expansion of its population and curb the normal development of the newly-established district to a varying extent, as in transport, electrical power, public facilities, education, culture, sanitation, etc. On the contrary, if the central city has a strong power, the new district will be granted more support of funds, policies and projects so as to promote its medical care and education, social security and employment as well as the transport to the urban level. Meanwhile, the central city will also set out to free up the district from multiple restrictions and insufficient development space. Before the administrative division adjustment, people from counties can't use their health insurance cards in hospitals or urban centers. Instead, they pay in cash and reimburse expenses when back to the county. However, the reimbursed proportion is relatively low. After the administrative division adjustment, public services like medical care, education or public transport could be shared throughout the city. Students from previous counties can also apply for high schools in the urban center; uniform planning will be conducive to the landing of more investment projects in the new district, cultivate more advanced business areas and propel the further development of modern manufacturing and service industries. Take Yongnian County of Handan as an example. Since the conversion from county to municipal district in 2016, new opportunities emerge despite a diminished independent power. Firstly, its development space is widened since the whole region is incorporated into the main urban area of Handan, which means all its land will become conditional construction land, effectively addressing the bottlenecks of land use. Secondly, it is able to share the investment platform of the city and enjoy urban preferential policies, generating great benefits for project construction and

industrial upgrading. Thirdly, the development of regional construction and economy is accelerated, as the whole area of Yongnian has been encompassed into the framework of urban planning so as to speed up the improvement in roads, water supply and drainage, squares, green fields and communication. Fourthly, the standard of social security is significantly increased, with the urban subsistence allowance raised from prior 450 yuan per person every month to 560 yuan and the rural subsistence allowance from 2820 yuan to 3072 yuan. In addition, the norms for medical care and social security will be in conformity with that of the citizens, and the remuneration for leading officials is also lifted to the urban level. Fifthly, bottlenecks of land use for construction in central areas of Handan are removed. For example, the previous Hanshan District was particularly constrained by land and space after years of development as a result of nearly exhausted land resources. Nevertheless, the adjustment of the administrative division provides spatial backup for its industrial restructuring and urban upgrading.

5.2 The Adjustment Costs of County-level Administrative District

Although the transformation of the county (county-level city) into a municipal district has multiple advantages, such as expanding urban space, optimizing resource allocation and industrial layout, there are also huge adjustment costs. Take the conversion of Kaifeng County to Xiangfu District of Kaifeng City in 2014 as an example^⑧, demonstrated mainly by changes in finance and taxation. After the administrative division adjustment, the government responsibilities remain unchanged; preferential policies from the state, province and city are still effective; regulation on land and planning together with the remuneration of leading officials and workers is adjusted accordingly. To be specific, the fiscal and tax system are kept unchanged temporarily, but financial pressures are intensified significantly. To begin with, part of the preferential policies from the state and province are cancelled. Previous financial subsidies, transfer payments and initiatives to benefit the people were reduced or abolished gradually, influencing every aspect of the economy and society. For example, previous training for new teachers at special posts in rural schools, the National Cultivation Plan, the basic equipment project for common high schools and the improvement plan for incompetent schools are outside of the support from higher-level authorities. Educational support funds from the nation

are cut down by almost 10 million yuan each year which amounted to 18 million yuan by 2017. Beyond that, despite the significance of previous Kaifeng County as one of the main suppliers of live pigs, the corresponding bonus was reduced annually and the large-scale standardized live pig breeding project was halted. The reduced supporting funds have totaled 7.8 million yuan with an annual reduction of 2.6 million yuan on average. Moreover, the annual subsidy of 3 million yuan to reform public hospitals at the county level was cancelled as well and the cancellation reached 12 million yuan by 2017. Apart from the above, after the administrative division adjustment, the nation ceased the disbursement of funds of 15 million yuan each year to the Public Security Bureau used for transfer payment and equipment. In a word, the deprived transfer payment for all four sectors above added up to 82.8 million yuan during the period from 2014 to 2017, which was rather striking compared with the local revenue of 719 million in 2014.

Apart from the costs discussed above, converting counties into municipal districts also drastically ramps up financial expenditures. Firstly, lifting the remuneration of leading officials and workers to the urban level^⑨ aggravates the financial burden of the new district. The current allowance for remuneration is 14,400 yuan per year in Xiangfu District and 22,800 in other districts. If the former keeps up with the latter, there will be an increased expense a total of 160 million yuan each year for workers on the job and retirees. It means, under the policy of remuneration adjustment by the State Council, the whole district has to bear a burden of another 160 million yuan, a fiscal gap of almost 320 million yuan. Secondly, funds for the regulation urban construction also rise due to higher criteria for infrastructures. After the administrative division adjustment, as Xiangfu District speeded up its connection to the urban centers, spending on urban construction continuously climbed from 61.02 million yuan in 2015 to 90.11 million yuan in 2016 and then to 131.43 million yuan in 2017. Money spent on the maintenance and purchase of environmental sanitation machinery, harmless disposal of wastes and improvement of public toilets goes rapidly. Next, better social security policies also boost financial expenses. For instance, according to the new rural cooperative medical insurance system, the payment from residents rose from 60 yuan every year to 120 yuan from 2014 to 2016, and in 2017 when the previous rural insurance system was integrated with that of non-working urban residents the

⑧ The relevant data is provided by relevant departments of the government of Kaifeng City.

⑨ Opinions of the Municipal Party Committee and the Municipal Government on the Implementation of Adjusting Some Administrative Divisions.

figure jumped to 150 yuan per year. Similarly, the old-age pension of Xiangfu District remained at 60 yuan per person each month before July 2014, but rose to 78 yuan soon afterward and then went up to 80 yuan in 2017.

The third drawback of converting counties(county-level cities) to municipal districts lies in the fact that it is hard to assume dual responsibilities of both counties and districts. By 2014, the total population of Kaifeng County was 757,600 but the urbanization rate remained at only 31.28%^⑩ with the majority coming from villages. Consequently, the municipal district has to shoulder the heavy responsibilities of both urban management and agricultural regulation. For this reason, Xiangfu District keeps the original number of 24 departments, 8 more than other districts, but that also leads to a relatively large number of people supported by district finance or by self-supported organizations. After administrative division adjustment, the municipal district is expected to not only accomplish the county's task of poverty alleviation and construction of better villages, but also assume the district's responsibilities to build a 'National Civilized City' and consolidate the achievement as a 'National Sanitary City'. The dual challenges increase both the workload and the difficulty.

6. Conclusions and Discussion

In summary, counties, county-level cities and municipal districts are three distinctive county-level administrative regions, which adapt to different stages of economic and social development respectively. The conversion from counties to county-level cities and counties (county-level cities) to municipal districts is an important embodiment of the transformation from traditional regional administrative area to urban administrative area and an important approach to the modernization of the county-level management system. The majority of residents are more likely to accept the establishment of county-level cities, but there are many different views on the establishment of county-level cities. The long-term suspending transformation work results in increasing phenomena such as expanding the county to reinforce its power, the province directly governing counties, and the emergence of development zones and new areas. The resulting adverse influence on economic development begins to emerge and existing researches concerned are relatively scanty. Therefore, the study on the institutional differences among counties, county-level cities and municipal districts as well as the conversion mechanism

possess critical importance. The conversion from counties to county-level cities and from counties (county-level cities) to municipal districts are both "double-edged swords". We should consider the problem as a whole and respond effectively to the actual needs of local economic and social development, especially keeping cautious of the conversion of counties (county-level cities) that have a large population but a low level of urbanization. In actual economic development, unnecessary or overdue adjustment of administrative division can incur contradiction between the system and reality. The adjustment of administrative division should be regarded as an important resource and a means of optimizing the allocation of resources to resolve the contradictions and substantially promote supply-side reform in administrative division field.

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^⑩ The data comes from 'the Statistical Yearbook of Henan Province in 2015.

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ARTICLE

Geo-spatial Analysis of the Impacts of Urbanization-induced Activities on Soil Quality in Port Harcourt Metropolis, Rivers State-Nigeria

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ABSTRACT

The study examined the impacts of urbanization-related activities on soil quality in Port Harcourt Metropolis-Rivers state, Nigeria. Experimental and survey research designs were employed in the study utilizing GIS and spatial analysis approaches. Both primary and secondary sources of data were used. The primary data were generated through laboratory analysis of soil samples from 15 randomly selected sites within the metropolis; and 800 valid copies of a socio-economic questionnaire administered to 800 respondents. Also, public hospitals were visited to ascertain the commonest soil-borne diseases in the area. Four research questions, four specific objectives and two hypotheses guided the study. The hypotheses were tested with one sample t-test and one sample chi square using SPSS. Standard scientific and laboratory procedures were followed in the collection and analysis of soil samples. Findings of the study include: urbanization-related activities (e.g. waste dumpsites, mechanic workshops, abattoirs, etc.) cause significant changes in soil quality in the area; and this results in the emergence of soil-borne diseases (e.g. Vascular warts, *Ascaris lumbricoides*, *Trichuris trichiura*, *Strongyloides stercoralis*) which affects residents' wellbeing. However, there is a significant difference in the perceived socio-economic effects of the diseases across the area. Specifically, laboratory results for soil analysis show that (mean values): pH 7.22, temperature 25.62 °C, PO₄ 0.342 mg/kg, Pb 120.62 mg/kg, K 66.81 mg/kg, NO₃ mg/kg. The study recommended for enforcement of physical planning and development control laws; regular evaluation of the quality of the soil, and restriction on the location of mechanic workshops and waste dumpsites around the metropolis.

1. Introduction

This study examined the impacts of urbanization-induced activities (such as mechanic workshops, refuse

disposal/waste dumpsites, abattoirs, disposal of industrial effluents and other chemicals on the earth's surface) on soil quality status in Port Harcourt metropolis, Rivers state; using GIS-based maps and spatial analysis approach

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to present the discussions.

Soil samples were collected and examined (in the laboratory) from 15 randomly selected sites/locations where the various land use activities outlined above, are taking place. These include: Egbelu, Mgbuosimini-Agip, Rumuekini, Rumuodara, Eneka, Nkpor, Eagle cement road-Rumuolumeni, East-West road by Nkpolu, Industry by NPA, Abuloma, Mile III mechanic village, Trans Amadi IA, GRA II, Old GRA by Forces Avenue, and D-Line. The various soil parameters examined in the work include pH, temperature, nitrate, phosphorus, lead, and potassium. In the analysis that follows, Figure 1 shows the soil sampling points while Figures 2 to 7 showcase the spatial occurrence of the various parameters in the soils of the area. While Table 5 summarizes the laboratory analytical report for the various parameters examined in the soils of the area.

1.1 Background to the Study

Urbanization is synonymous with urban outward growth (which is a reflection of urban land use activities). As a spatial process, the physical and social manifestations of urbanization bring about an increase in urban land use activities and outward growth (physical expansion) of the urban center, growth in economic activities, rise in population and demographic characteristics as well as the sophistication of towns and cities. It represents a functional relationship between the existing population and available land. It is been influenced by changes in technology, state policy, economic, demographic and cultural values ^[1,2]. It is also associated with modernism and improvement in means of production and the wellbeing of the citizenry.

Nevertheless, an increase in urban land use activities or urbanization is a two-sided coin that is associated with both positive and negative impacts. The outward growth and intensification of the internal structure of towns affect the physical environment through the impacts of the activities that go on in that space. It has negative consequences on human health and the environment including the development of slums ^[3,1].

As a process, urbanization and the growth of towns or cities did not start today nor did it just happen overnight. Rather, it is a long process that starts from the initial gathering of a few persons and later on a high number of people in one location (space), and the need to survive or change their lifestyles through engagement in economic activities.

The evolution of cities from their earliest origins more than 5, 500 years ago through the Industrial Revolution which began (in the English Midlands) in the mid-1700s,

marked the origin of urban development or urbanization, which later trickled down into other parts of the world. A lot of changes (social, cultural, economic, political, technological and environmental processes; including merchant capitalism, colonialism, and industrialization) took place during this long span of urban development and redevelopment ^[1,3-5].

Notably, five regions of the world provided the earliest evidence for urbanization and urban civilization. These are Mesopotamia, Egypt, the Indus Valley, Northern China, and Mesoamerica. Examination of the internal structure of these cities – their street patterns, religious precincts, different neighborhoods, etc., reveals a great deal about their evolution and the political, economic and social changes that can be seen in them ^[3,5]. In Nigeria, evidence of the impacts of such changes can also be seen in the internal structures of ancient cities and towns like Benin, Kano, Ibadan, Abeokuta, Ile-Ife, Osogbo, Zaria, Ilorin, etc. ^[1].

Many scholars argued that urbanization in these ancient Nigerian cities predated western civilization. Long before the Europeans and Portuguese came to Nigeria and some West African States, there were already existing well-planned street layouts, broad roads and well-organized systems. This fact was also acknowledged by the Whites themselves when they saw the level of planned layouts and roads especially around the Kings (as in Benin) and Emirs (as in Kano, Zaria) Palaces ^[1,6,7].

It is pertinent to reiterate here that, urbanization has been a dynamic process, leading to environmental pollution. Major forms of urban pollution in Port Harcourt include an increase in the volume of sewage and solid waste generation and the burden of effective disposal; a rise in urban noise pollution levels from factory machinery, transportation vehicles, and the rising cases of sleeplessness and hearing impairments; soil pollution and the contamination of food crops cultivated on polluted soils; water pollution and contamination of sea foods and drinking water sources; air pollution and increase cases of respiratory disorders, itching eyes and defacing of buildings and material objects. Others include urban sprawl and disappearing urban-fringe green areas including the loss of rural forested lands ^[8,9].

This is a result of the uncontrolled high rate of urban expansion that is taking place within the Port Harcourt region. At its inception in 1912, Port Harcourt which was established just about 66 km from the Atlantic Ocean was just about 180,000 hectares or 25 km²; it grew to 16.25 km² in 1976 and 282.25 km² by 1995. Today, the city has grown to engulf more distant fringes like Nkpor, Aluu, Rukpokwu, Eneka, Elioju, Elemenwo, Woji, Akpajo etc. ^[1,10-15].

The main reasons for this high rate of outward expansion of the city of Port Harcourt include its strategic location on a plain topography with good natural harbours, abundance of groundwater (freshwater) reservoirs of great horizontal and vertical extent, an abundance of hydrocarbon deposits within the Port Harcourt region and fertile soils for agriculture at the fringes for a constant supply of food for the growing urban population, presence of crude oil and gas multinational corporations and allied industries. Others are favourable climate and conducive environment that is not harsh, presents of many institutions, including the hospitality industry, high level of commercial activities, very high population concentration which provides large and cheap labour pool, relative political stability, social activities and verse land (at the fringes) for housing and infrastructural development.

This high rate of urbanization in Port Harcourt is associated with a rise in pollution levels with severe consequences on the health of the residents and the environment generally. It is on this premise that this study seeks to examine the impact of urbanization on the soil pollution status of the Port Harcourt metropolis.

Walker (2007) ^[16] examined the effects of urbanization across the globe and argued that an efficient system of coordination of urban activities is lacking especially in the less developed world. Urbanization in these developing economies is associated with a rise in environmental deterioration and the proliferation of slums and squatters. Obnoriz in his study of urban development and urbanization processes in Africa, postulated that most traditional African cities lack a well-planned system to monitor and control urban growth and development. Hence, most cities in Africa, are seldom with the problem of uncoordinated urban growth and development of ghettos, environmental pollution and degradation, resources over-exploitation, lawlessness and rise in crime rate ^[17].

The doyen of African urbanization, Mabogunje in his study of African urbanization and Ukpere in work on urban environmental management crisis Africa, argued that the drive towards urbanization in Nigeria and in Africa in general, led to an unprecedented rise in urban population and economic activities in most of the earliest urban centres especially the capital cities, coastal towns with good harbours (e.g. Lagos, Port Harcourt, Calabar, Dakar, Lome, Mauritius, Port Said, Durban) and other towns associated with solid mineral mining activities like Jos, Abeokuta, Enugu, Johannesburg, Cape Town, Monrovia, Darfur, Khartoum, etc. ^[7,18]. That, urbanization in Africa is characterized by growing social and environmental challenges or crises such as a rise in urban population and unemployment, high cost of

living, increase in crime rate, housing inadequacies and the emergence of slums and squatter settlements, rise in pressure on natural resources utilization and available infrastructures, increase in industrial related activities and rising cases of pollution of urban airspace, land (soil) and drinking water sources ^[7,18].

Lastly, Ukpere and Igwe examined the environmental and social effects of air pollution in Port Harcourt; and argued that urbanization-induced activities have resulted in a steady increase in the level of air pollution with severe consequences on the health of residents and properties in the city. They called for the immediate adoption of measures aimed at cutting down activities that promotes air pollution in the area ^[19]. Other works which x-tray the side effects of urbanization include Wizer and Elekwachi who 2020 studied the impacts of urbanization and wetlands loss in Obio/Akpor; Wizer and Mpigi in 2020, studied the emergence of flood in the Port Harcourt metropolis due to uncontrolled urbanization and poor physical planning; and Weli, Okoli and Worlu in 2020 examined the impacts of urban sprawl dynamics on surface temperature characteristics variability in the Greater Greater Port Harcourt Region ^[20-22].

There are identified gaps (scope, spatio-temporal and methodological) in the previous works. The works cited so far did not actually examine the effects of urbanization on the soil pollution status of Port Harcourt as a topic. Again, most of the studies ^[16,23,7] were carried out outside the shores of Port Harcourt. This forms the gap in the literature which this study seeks to address by holistically examining the effects of urbanization on the soil pollution status of Port Harcourt using GIS, survey and experimental research designs.

1.2 Research Questions

Arising from the statement of the problem, the following questions were raised in order to guide the study:

- i. Does urbanization-induced activities pose any significant threat to soil pollution in the City?
- ii. What are some of the urbanization-induced activities that pose threat to soil quality in the City?
- iii. What are some of the pollution-induced are diseases prevalent in the Metropolis?
- iv. Does the emergence of the perceived pollution-induced soil-borne diseases pose any significant effect on the socio-economic development of the people of the area?

1.3 Aim and Objectives of the Study

The aim of this study was to examine the impact of urbanization-induced activities on soil quality status in the

Port Harcourt metropolis, Rivers State using geo-spatial techniques. The following specific objectives guided the study. To:

- (i) examine the impacts of urbanization-related activities on the soil pollution status of Port Harcourt Metropolis through laboratory analysis of soil samples;
- (ii) find out the types of pollution-induced soil-borne diseases that are prevalent in the area;
- (iii) ascertain the perceived effects of the diseases on the socio-economic development of residents of the study area.
- (iv) produce geo-spatial maps of the soil pollution status of the area.

1.4 Hypotheses

The following hypotheses were postulated to direct the study:

H₁: Urbanization-related activities do not cause any significant change in soil-borne (soil pollution) and the emergence of certain soil borne diseases in the area.

H₂ there is no significant difference in the perceived effects of pollution-induced soil-borne diseases on the socio-economic lives of residents in the area.

1.5 The Study Area

Location and Extent

The present-day Port Harcourt metropolis is comprised of Obio/Akpor and Port Harcourt local government areas. It is located between latitudes 04° 43' and 04° 57' N and between longitudes 06° 53' and 08° 08' E. It is approximately 664 km² (i.e. Obalga 392 km² and Phalga 272 km²). It is ever-expanding and has since exceeded its initial limits (of 25 km² in 1912) nearly 27 times. It is now made up of Obio/Akpor and Port Harcourt City Council Local Government Areas, with an increasing trend to engulf major parts of Ikwerre, Etche, Omuma, Oyibo, Eleme and Okrika local government areas, which are part of what is now called Greater Port Harcourt region. Its westward expansion is gradually sprawling to Emohua local government area. It shares a boundary with the following local government areas: it is bounded to the north by Ikwerre and Etche, north-east by Etche; to the south by Okrika; to the east by Oyigbo and Eleme; and to the west by Emohua and Degema.

Port Harcourt falls within the limits of the humid tropics. Its climate is predominantly tropical humid and is being influenced by land and sea breezes and the two

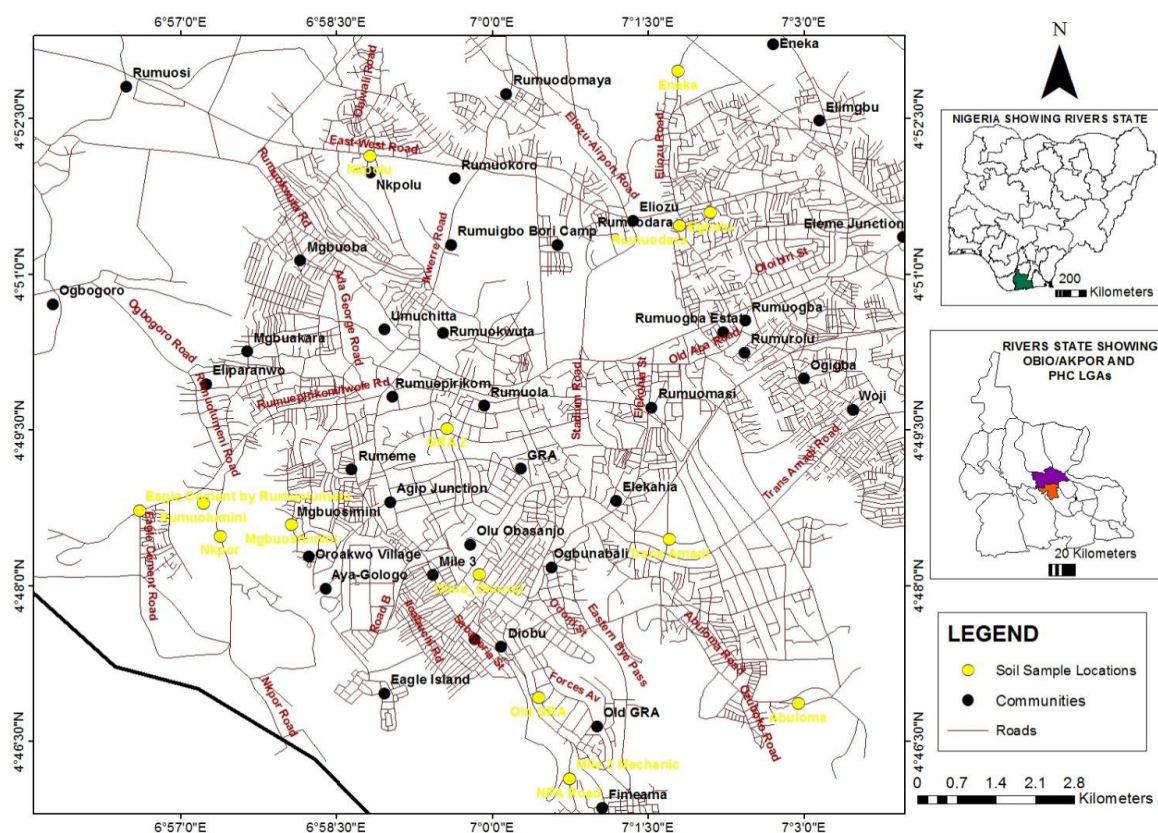


Figure 1. Port Harcourt Metropolis showing soil sampling points

Source: Researcher's field work and analysis, 2020 digitized from the original map, Ministry of Lands & Survey, Port Harcourt

major pressure and wind system namely the South-West (S-W) and North –East (N-E) trade winds. The moist south-west trade wind originates over the South Atlantic Ocean and blows over Port Harcourt between the months of February to November, bringing the rains.

The north-east trade wind brings dry conditions having passed over the hot, dry Sahara desert to reach Nigeria from the north and blows over Port Harcourt between the months of November/ December and January /February of the year. These two wind systems meet at the Inter-Tropical Convergence Zone (ITCZ) when the contact is on land and Inter-Tropical Discontinuity (ITD) when the contact is over the ocean. The mean daily temperature does not exceed 32 °C, while the mean monthly maximum temperature is 33 °C, the mean monthly minimum temperature is 28 °C, mean annual temperature is 28 °C with an annual range of 3.08 °C. The humidity content in the area is 85%. Also, the intensity of the harmattan is very low mainly due to the nearness of the city to the moderating influences of the sea ^[1].

Ukpere in his study, revealed that, February has the highest intensity (5.68%) followed by January and December (5.50%). That, the effective temperature index (ET.) and wind chill index for the harmattan periods is not below 27% (mean E.T) in each month. Consequently, Port Harcourt is said to be less conducive during these periods of effective temperature index and wind chill index. The mean wind chill figures viz (20.29 K, 33.45 K, 63.21 K and 68.94 K) in January, February, November and December respectively reveal relatively low wind chill which has a small soothing effect on the high E.T of December to February which show slight higher variations. Rainfall in the area exhibits a double maxima regime with peaks in July and September with a little dry season in August (August break). The highest monthly rainfall of 3,496.1 mm and 3, 578.4 mm occurs in July and August respectively. The mean onset date of rainfall in Port Harcourt is 27 February while the end of the rains is 26th November; also, the mean length of the rainy season is 272 days ^[1].

About vegetation, there is hardly any vegetation in Port Harcourt apart from a few mangroves. This is because; the vegetation of the area is fast disappearing due to urban sprawl which has resulted in a functional succession and invasion (colonization) of the neighbourhood lands and reclamation of low/wetlands.

2. Methodology

Experimental and survey research designs were adopted for the study; utilizing both primary and secondary sources of data. The primary data which is the main focus

of this study, were generated through laboratory analysis of soil samples collected from 15 different sites within the city and GIS soft wares (Arch GIS, Erdas imager, QGIS, etc), were deployed to produce GIS-based maps in order to showcase the spatial dimension of the level of occurrence of the various parameters in the soils of the area.

Man and his activities in any location are at the centre of environmental pollution across the globe. Thus, an increase in population causes a corresponding increase in land use activities. Apart from the main city center where different land use activities exist, there are over 30 fringe settlements located within and around Port Harcourt, where there are lots of urbanization-induced activities taking place. According to the National Population Commission (NPC, 2010), Port Harcourt's population as projected for 2010 was 1,146,721 while the total number of regular households was 298,180. At the national growth rate of 2.7%, the researchers projected the NPC 2010 population figures of 1,146,721 to 2020 which is 3,019,981 persons while an approximate number of regular households is 596,359 (based on the National average household size of 6 persons per household). However, the United Nations Global Urban Population estimates, put the population figure of the Port Harcourt metropolis to be 3,020,000 in 2020 ^[24].

However, through the use of a simple random sampling technique, a sample size of 800 respondents was used to gather basic socio-economic data regarding main economic activities, soil borne diseases arising from soil pollution, etc.

2.1 Soil Samples Collection and Analysis

Basic tools were implored for soil sample collection. These include calibrated meter rule, clean cellophane bags and small transparent rubber plates with cover, GPS, open auger, masking tape, bold-pen, hand trowel and shovel. The earth at each of the sites was dug out and soil samples were collected at 0-30 cm depths. Soil samples were collected from 15 randomly selected sites/areas prone to intense land-use activities like mechanic garages, motor parks, refuse disposal points, commercial and institutional centres. Each sample was appropriately labeled at the site before moving to the laboratory. Parameters examined included microbial and certain physicochemical parameters such as temperature, pH, Nitrogen, TOC, Phosphorus, Potassium, Lead, Iron, Calcium, Magnesium, and particle characterization. The 15 randomly selected sites/locations include: Egbelu, Mgbuosimini-Agip, Rumuekini, Rumuodara, Eneka, Nkpor, Eagle cement road-Rumuolumeni, East-West road by Nkpolu, Industry

by NPA, Abuloma, Mile III mechanic village, Trans Amadi IA, GRA II, Old GRA by Forces Avenue, and D-Line.

2.2 Methods of Data Analysis

A simple percentage was used to analyze the questions which were framed in tandem with the objectives of the study which centred on basic social issues of the research. While the stated hypotheses were analyzed with one sample students' t-test and chi square at the 0.05 level of significance using SPSS.

3. Results and Discussion

Table 1. Urbanization-related Activities and Soil Pollution in Port Harcourt Metropolis

S/N	Statement: Urbanization- induced activities causes soil pollution in Port Harcourt	Frequency of Response				Total
		SA	A	D	SD	
1.	Obalga Freq. %	300	87	08	05	400
		75	21.75	2	1.3	100%
2.	Phalga Freq. %	304	72	14	10	400
		76	18	3.5	2.5	100%
Grand Total Percentage		604	159	22	15	800
		75.5	19.8	2.8	1.9	100%

Source: Researcher's Fieldwork and analysis, 2021

From Table 1, 75.5% of the respondents strongly agreed that urbanization-related activities cause soil pollution in the city, another 19.8% also agreed; 2.8% disagreed and another 1.9% others also strongly disagreed. Since the agreed responses (95.38%) are more than the disagreed responses (4.63%), the study therefore concluded that urbanization-induced activities cause soil pollution in the metropolis.

From Table 2, 48% of the respondents strongly agreed that urbanization-induced soil pollution causes the emergence of soil-borne diseases in the city. Another 45.6% of others also agreed; while 3% disagreed and another 3.4% others also strongly disagreed. Since the agreed responses (93.63%) are more than the disagreed responses (6.38%), the study therefore concluded that urbanization-induced soil pollution causes the emergence of soil-borne diseases in the metropolis.

Table 2. Urbanization-induced Pollution and the emergence of soil borne diseases in Port Harcourt Metropolis

S/N	Statement: Urbanization- induced Pollution causes the emergence of soil borne diseases in Port Harcourt	Frequency of Response				Total
		SA	A	D	SD	
1.	Obalga Freq. %	200	183	10	07	400
		50	45.75	2.5	1.75	100%
2.	Phalga Freq. %	184	182	14	20	400
		46	45.5	3.5	5	100%
Grand Total Percentage		384	365	24	27	800
		48	45.6	3	3.4	100%

Source: Researcher's Fieldwork and analysis, 2021

From Table 3, 3.1% of the soil-borne diseases occurred in January, 4.6% in February, March (14.8%), April (17.6%), May (14.2%), June (6.1%), July (4.4%), August (15.3%), September (8.9), October (5.5%), November (3.7%), and December (1.9). In terms of spatial spread, the dry season months of December have the least occurrence (1.9%) followed by January (3.1%) and November (3.7%). While the rainy season month of April has the highest rate of 17.6%, followed by August (15.3%) and May (14.2%). While most of the diseases occur during the rainy season months (which are also the peak period where microbial pollutants in the soil are spread in the area under the aid of the rains and poor sanitary conditions of most places), Ascaris lumbricoid and Trichuris trichiura thrives well in the soil of the area especially in the wet season months of April–August.

From Table 4, 52% of the 800 respondents strongly agreed that the emergence of pollution-induced diseases affects the socio-economic development of the people of the area, another 44.9% also agreed; 1.6% disagreed and another 1.5% strongly disagreed. Since the agreed responses (96.88%) are by far more than the disagreed responses (1.66%), the study therefore concluded that the emergence of the diseases affects households' socio-economic development in the study area.

3.1 Urbanization-related Landuse Activities that Pose Threat to Soil Quality in Port Harcourt Metropolis

An increase in urban population will result in an increase in land use or urbanization-related activities which in the long run, result in the tampering of the status of the soil around our urban centres Port Harcourt metropolis

Table 3. Hospital Records on common Soil-borne diseases often suffered by household members

Diseases	Reported cases (Monthly summary) 2019-2020													
	Jan 1	Feb 2	Mar 3	Apr 4	May 5	Jun 6	Jul 7	Aug 8	Sep 9	Oct 10	Nov 11	Dec 12	Total	%
Vascular witts	24	57	27	8	32	34	3	30	39	12	17	2	285	13.0
Strongloids stereoralis	11	12	23	42	33	45	34	38	47	39	2	-	326	14.9
Ascaris lumbricoids	18	19	172	183	123	27	30	137	58	38	31	20	856	39.0
Trichuris trichiura	14	13	102	153	123	27	30	131	50	32	31	20	726	33.1
Grand total	67	101	324	386	311	133	97	336	194	121	81	42	2193	
%	3.1	4.6	14.8	17.6	14.2	6.1	4.4	15.3	8.9	5.5	3.7	1.9		100

Source: Researcher's fieldwork 2020, compiled from Public Hospital/Primary Health Centres in the area, 2015-2020

Table 4. Perceived Socio-economic impacts of Pollution-induced diseases on households in the area

S/N	Statement: The emergence of the diseases/ illnesses affects the socio- economic development of your household	Frequency of Response				Total
		SA	A	D	SD	
1.	Obalga	204	184	05	07	400
2.	Phalga	212	175	08	05	400
Grand Total		416	359	13	12	800
Percentage		52	44.9	1.6	1.5	100%

Source: Researcher's Fieldwork and analysis, 2020

is not an exception. From our investigations, the main urbanization-induced land use activities that threaten soil quality in the Port Harcourt metropolis include: industrial manufacturing and processing activities, urban agriculture (use of agrochemicals), mechanic workshops, waste disposal activities, abattoir activities, etc. The various soil parameters examined in the work include pH, temperature, nitrate, phosphorus, lead, and potassium. In the analysis that follows, Figure 1 shows the soil sampling points while Figures 2 to 7 showcase the spatial occurrence of the various parameters in the soils of the area. While Table 5 summarizes the laboratory analytical report for the various parameters examined in the soils of the area.

3.2 Urban Land Use Activities and Spatial Variability of Soil Quality in Port Harcourt Metropolis

The spatial variability in soil quality of the area is presented in the table below and as displayed in the various GIS-based maps.

Method Source "American Society for Testing and Materials" (ASTM) 2010

"American Public Health Association" (APHA) 20th Edition 2005.

The spatial occurrence of the various parameters in the soils of the area is described below with the aid of GIS maps.

Table 5. Result of Laboratory Analysis for Soil Samples

S/N	Coordinates	Date/ Time	Sample ID	Depth (cm)	pH APHA 4500-H+	Temp APHA 2550-B	NO-3 APHA 4500-B mg/kg	PO4 APHA 4500-P mg/kg	Pb ASTM D3559 mg/kg	K ASTM D4192 mg/kg
	DPR									210
1	N:04.76911°	9/11/21	Mile 3 Mech.	0-15	7.1	25.3	2.2	0.29	116.2	35.62
	E:007.01235°	1:45pm		15-30	7.1	24.7	6.3	0.47	118.0	38.45
2	N:04.81016°	10/11/21	Eagle Cem. Rd	0-15	6.6	25.8	0.0	0.03	99.63	86.90
	E:006.94325°	11:53am		15-30	6.8	25.3	0.5	0.15	104.5	98.22
3	N:04.80556°	10/11/21	Nkpor	0-15	7.3	25.5	0.8	0.03	<0.001	78.43
	E:006.95705°	12:05am		15-30	5.7	24.8	1.8	0.02	<0.001	80.12
4	N:034.84415°	10/11/21	Egbelu	0-15	5.9	25.1	0.3	0.00	91.48	86.42
	E:006.94042°	1:10pm		15-30	6.4	25.6	1.2	0.08	69.47	78.43
5	N:04.80264°	10/11/21	Mgbuoshimiri	0-15	6.8	25.5	0.6	0.24	46.81	76.42
	E:006.07278°	13:50pm		15-30	6.9	26.1	0.9	0.63	52.35	65.78
6	N:04.78116°	11/11/21	Abuloma	0-15	6.7	25.5	1.3	0.15	22.52	56.42
	E:007.04910°	10:30am		15-30	6.6	25.1	2.0	0.36	28.93	62.13
7	N:04.80752°	10/11/21	Trans Amadi	0-15	6.7	25.3	0.7	0.10	29.71	35.43
	E:007.02839°	10:41 am		15-30	7.7	25.8	0.9	0.40	30.94	40.13
8	N:04.78215°	12/11/21	Old GRA/	0-15	6.4	24.9	0.1	0.01	<0,001	74.12
	E:007.00735°	9:50am		15-30	6.5	25.1	0.1	0.01	<0.001	76.14
9	N:04.80187°	12/11/21	Dline/Okokoji	0-15	7.7	25.5	0.5	0.05	87.57	89.57
	E:006.99783°	11:05am		15-30	6.5	25.5	1.2	0.05	90.24	86.13
10	N:04.82536°	12/11/21	GRA II	0-15	6.2	25.6	0.7	0.08	45.76	56.35
	E:006.9927°	11:35am		15-30	6.4	25.6	1.3	0.17	50.08	55.48
11	N:04.86021°	13/11/21	Rumudara	0-15	7.8	25.1	0.4	0.16	198.5	80.56
	E:006.02929°	10:10am		15-30	6.9	25.0	0.8	0.38	209.1	80.44
12	N:04.88258°	13/11/21	Eneka	0-15	8.2	25.4	0.9	0.15	4.001	70.41
	E:006.03002°	10:30am		15-30	7.7	25.3	1.8	0.38	5.327	68.42
13	N:04.88256°	13/11/21	Rumuekini	0-15	7.0	25.5	1.3	0.26	119.0	62.80
	E:006.94113°	11:20am		15-30	6.2	25.4	2.6	0.41	144.5	64.78
14	N:04.86912°	13/11/21	Nkpolu	0-15	6.7	25.3	1.0	0.10	97.54	79.55
	E:006.9803°	12:16		15-30	6.3	25.4	1.2	0.28	26.82	80.45
15	N04.76911°	9/11/21	NPA Rd	0-15	6.6	25.6	0.1	0.00	63.37	32.46
	E007.01235°	10:55am		15-30	6.7	25.3	0.0	0.02	183.5	34.13

Source: Researcher's fieldwork and analysis, 2020

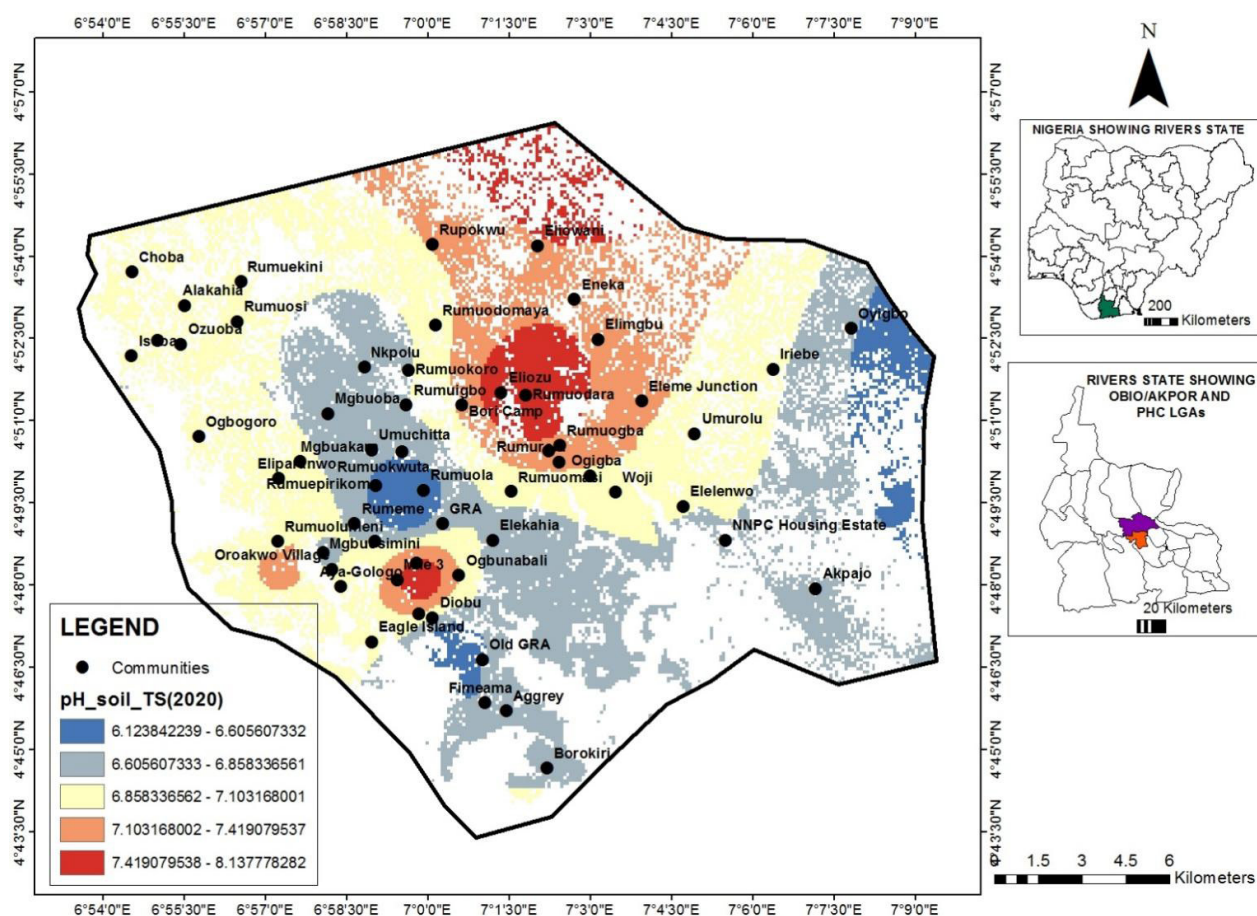


Figure 2. Port Harcourt Metropolis showing soil pH level

Source: Researcher's field work and analysis, 2020

pH level in the soil of the area ranges from 6.1 to 8.14; and a mean occurrence of 7.22 in 2020. In terms of spatial spread, soil pH ranges from 6.12 to 6.61 around the central part of Rumuola and north-east near Oyiibo; 6.61 to 6.86 in virtually all around the eastern and southern parts of the metropolis; 6.86 to 7.10 around the west, south-west, north-east and north-western parts of the area; 7.10 to 7.42 at the Diobu area and Ogbunabli, north and central spots. It ranges from 7.42 to 8.14 in the north-central part of the metropolis.

While some of the soils indicated alkaline, others were neutral and a few others acidic. pH value was 7.1 around Mile 3 mechanic village, 6.6 at the Eagle cement area, Abuloma, and NPA road; 7.3 at Nkpor; 5.9 at Egbelu; 6.8 at Mgboshimini Agip; 6.7 around Trans-Amadi; 6.4 around Old GRA/Forces Avenue; 6.5 in D/Line; 6.3 at GRA Phase 2; 7.7 around Rumuodara. The highest figure of 8.2 was recorded at Eneka while the least figure of 5.7 was recorded at Nkpor.

Soil temperature is almost the same across the metropolis. It ranges from 24.31 to 26.10 °C with a mean

of 25.6 °C. Soil temperature ranges from 24.31 to 24.95 °C around the North Central, South-West, and south-Eastern parts; 24.95-25.39 °C around the entire west, north and eastern spots. The temperature rises from 25.0 to 25.58 °C mostly around the central, extreme northeast, and eastern flank. The highest values 25.57 to 26.10 °C occurs around the central spot near Elekahia and Ogbunabli and the western flank near Rumuolueni and Mgbuosimini. Some of the sites with the highest temperature values include Ogbuosimini (26.1 °C), Egbelu (25.6 °C), and Eagle cement area (25.3 °C). The least value was recorded at mile 3 mechanic village.

Phosphorous (PO_4) values range from 0.010 to 0.629 mg/L and a mean of 0.342 mg/L in 2020. PO_4 values are lower (0.0100 - 0.146mg/L) at the south around Diobu, Eagle Island and Fimeama; low (0.146 - 0.233 mg/L) at the extreme North-West, North-North, North-East, and eastern parts of the metropolis Moderate (0.233-0.294 mg/L) around the north, entire east; high (0.294-0.408 mg/L) at the centre and west of the metropolis; it is relatively very high (0.418-0.629 mg/L) west of the central bloc. Some

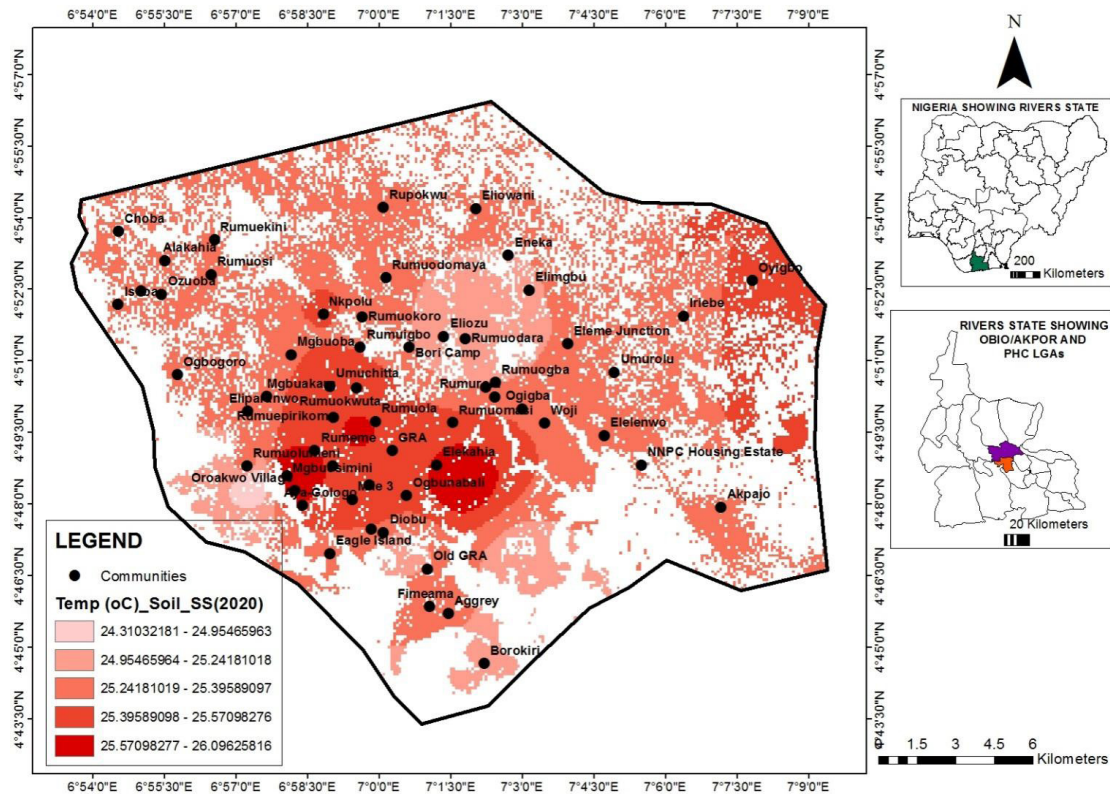


Figure 3. Port Harcourt Metropolis showing soil Temperature (°C) level

Source: Researcher's field work and analysis, 2020

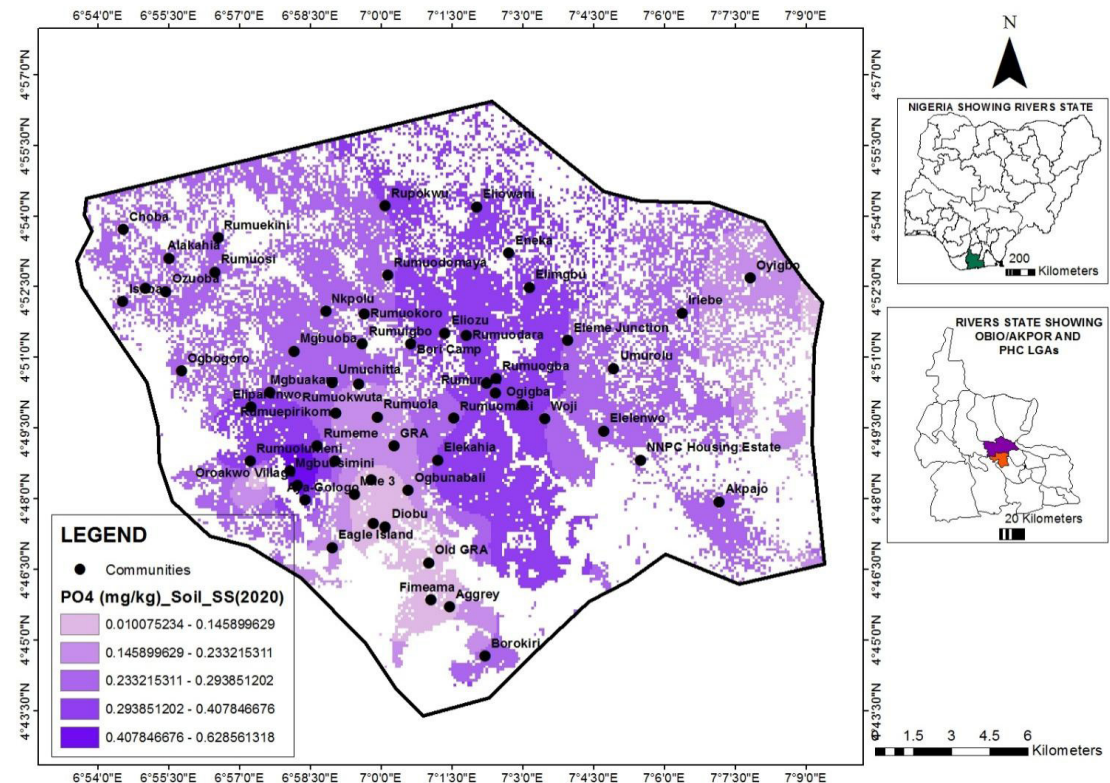


Figure 4. Port Harcourt Metropolis showing soil Phosphate (mg/kg) level

Source: Researcher's field work and analysis, 2020

of the communities/sites with relatively very high soil temperature figures include Mgbuosimini-Agip (0.63 mg/L), mile 3 mechanic workshop (0.47 mg/L), Rumuolumeni (0.41 mg/L), Trans-Amadi 1. A (0.4 mg/L), Abuloma (0.38 mg/L), Rumuodara (0.38 mg/L) and Eneka (0.38 mg/L). Whereas some sites recorded the least values e.g NPA (0.02 mg/L), Nkpolu (0.10 mg/L), D/line (0.05 mg/L), GRA I (0.08 mg/L), Nkpor (0.02mg/L), Egbelu (0.08 mg/L), etc.

Lead (Pb) occurrence level in the soils ranges from 0.075-208.90 mg/kg and a mean of 120.62 mg/kg for the 15 sampled sites in the area. At the moment (2020), Pb values range from 0.074-56.58 mg/kg west of the north-central, south-central around Ogbunabali and Eastern-bypass; 56.58-79.51 mg/kg in most places stretching from north-west, west, north-north, and east in a ring of 79.51-108.17 mg/kg at the north-central and down south-south of the metropolis surrounding Borokiri and near Orakwo village at the western flank. It is within the range 108.17-149.94 mg/kg at the north-central and south around Aggrey and Finema.

Urbanization-induced land use activities (agriculture,

mechanic workshops, industries, refuse disposal, etc.) can either cause an increase or lowering of the amount of Potassium in the soil. When it is low, it affects crop yield and when it is in excess, it results in pollution; and under the influence of surface run-off, it is watched into streams thus polluting surface water. The level of Potassium in the soil of the metropolis ranges from 34.19 to 89.57 mg/kg with a mean occurrence level of 66.81 mg/kg. The figures are higher (65-89 mg/kg) around the west, north and north-eastern parts; and low (50-55 mg/kg) around the east and southern parts; very low (34-50 mg/kg) around the most central part of the south.

Nitrates level ranges from 0.001 to 3.30 mg/L with a mean of 1.65 mg/kg. The level of nitrates varies across the 15 sampling points of the areas. At the extreme eastern, western and south-western area, the values range from 0.00 to 0.68 mg/kg; 0.68 to 1.11 mg/kg at the centre around Eliozi, Rumuodara, Bori camp, and Oginigba, also at the west near eagle island, southern communities of Aggrey, old GRA; 1.11 To 1.38 mg/kg around most of the north, east, and west flank; 1.38 to 1.81 mg/kg at the west, east

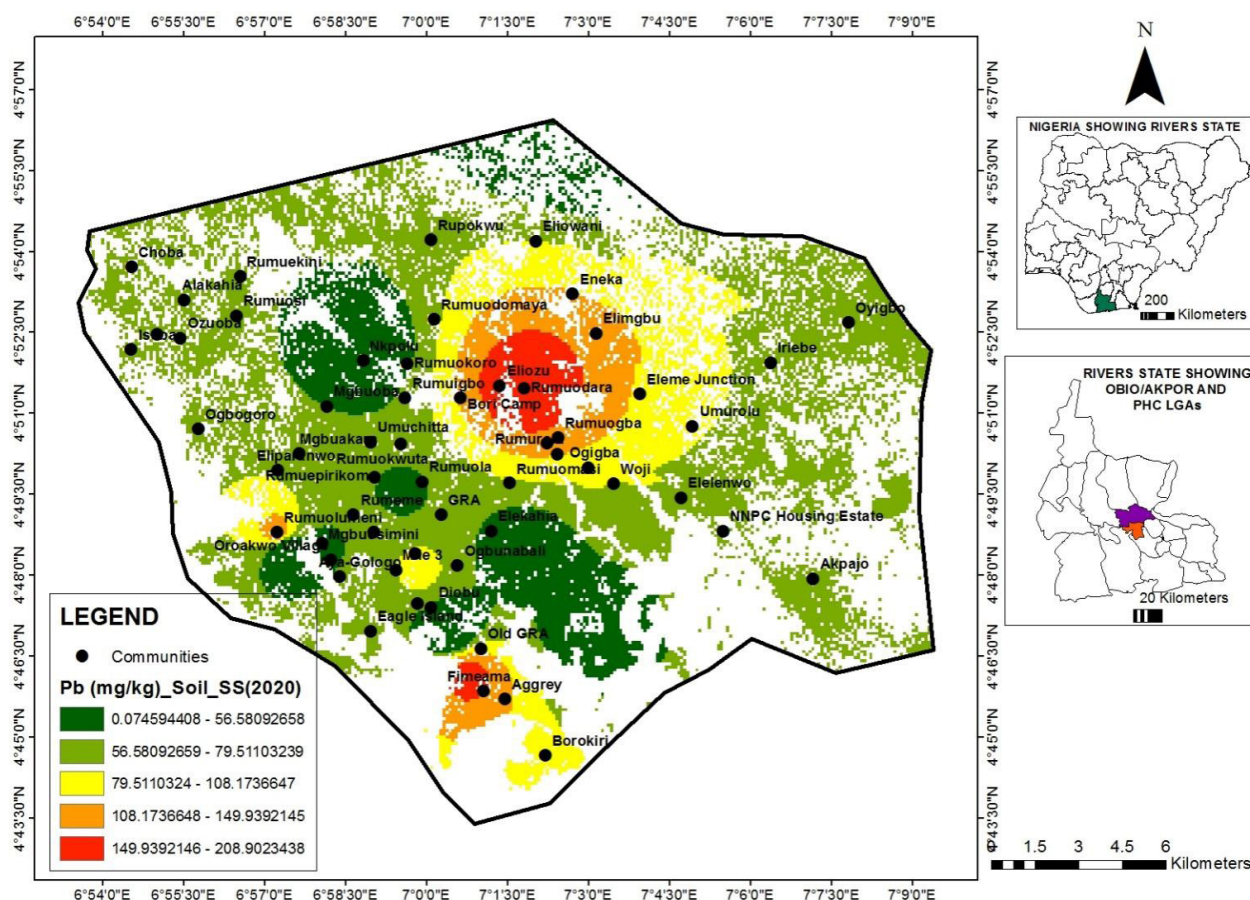


Figure 5. Port Harcourt Metropolis showing soil Lead (Pb) (°C) level

Source: Researcher's field work and analysis, 2020

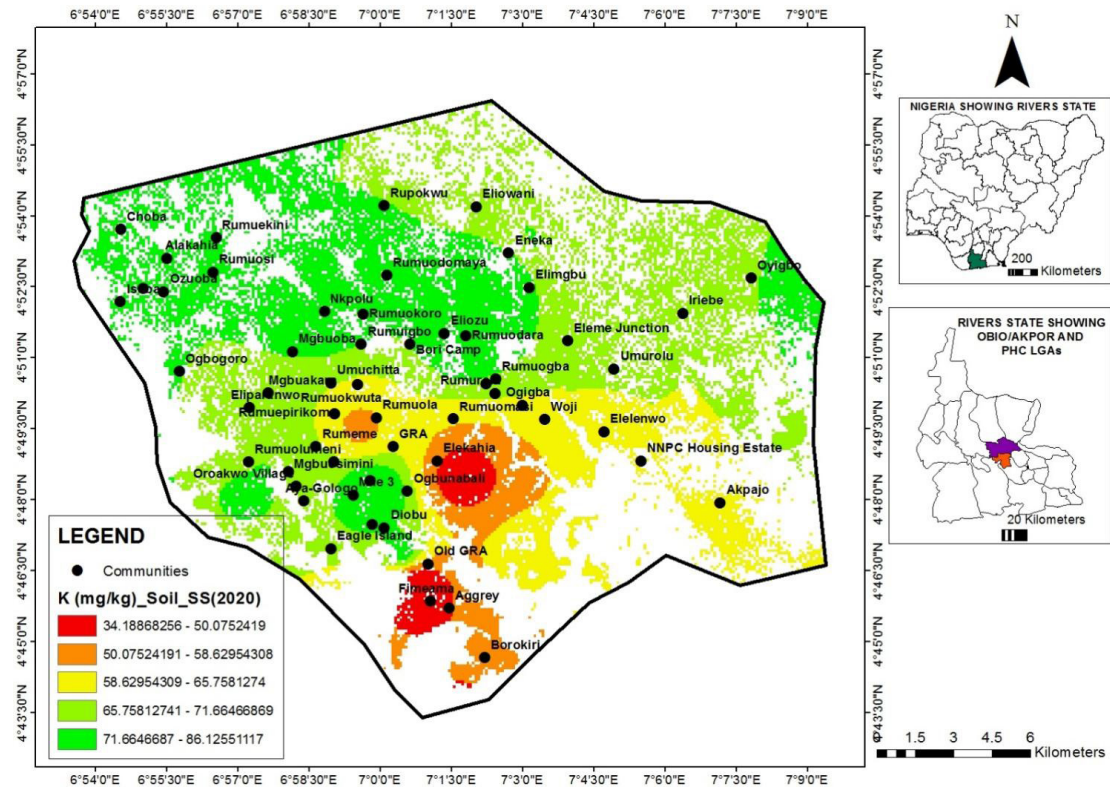


Figure 6. Potassium (mg/kg) Concentration ($\mu\text{g}/\text{m}^3$) in the soils of Port Harcourt Metropolis

Source: Researcher's fieldwork and analysis, 2020

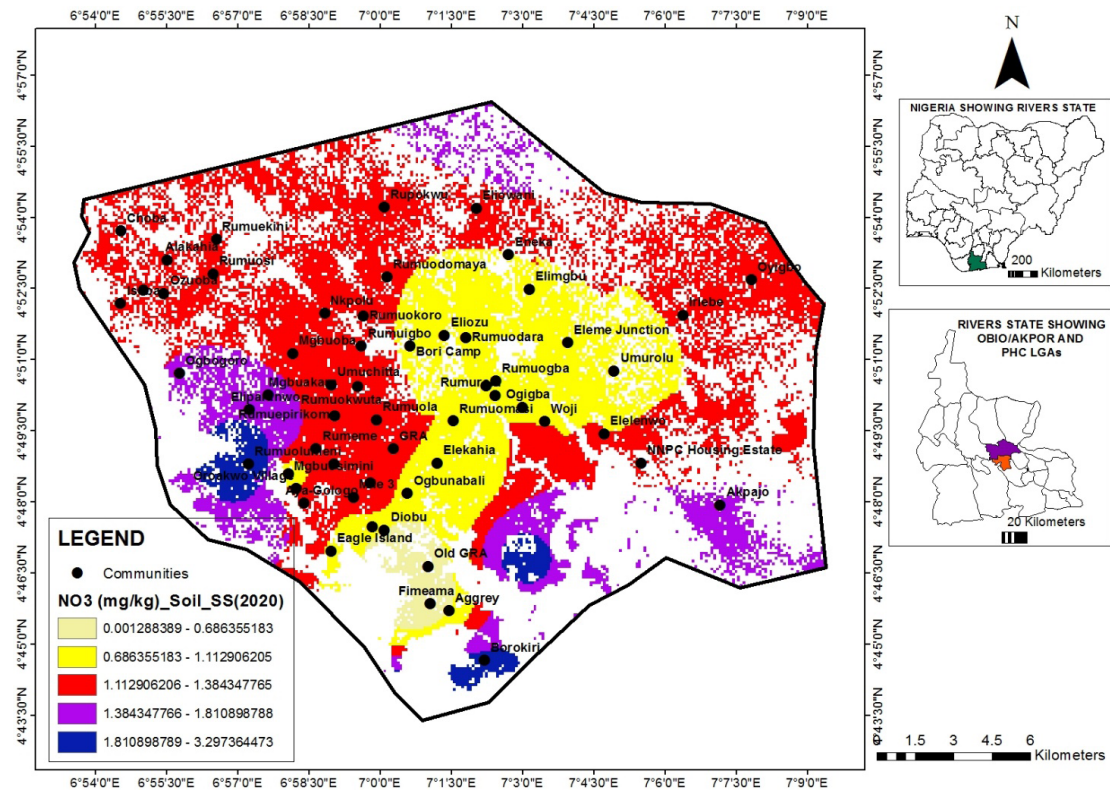


Figure 7. Nitrates (mg/kg) Concentration ($\mu\text{g}/\text{m}^3$) in the soils of Port Harcourt Metropolis.

Source: Researcher's fieldwork and analysis, 2020

and south-eastern bloc; and between 1.8 to 3.30 mg/kg around the extreme south of the metropolis.

One striking fact about the soil analysis is that, in almost the 15 sampled points, most of the parameter values increase with an increase in depth from 0-15 and 15-30 cm. For example, while pH (7.1) was the same for mile 3 mechanic workshops, NO_3 in 2020 increased from 2.2 mg/kg (at 0-15 cm depth) to 6.3 mg/kg (at 15-30 cm depth). PO_4 rose from 0.29 mg/kg (0-15 cm) to 0.47 mg/kg (15-30 cm); Pb increased from 116.2 mg/kg (0-15 cm) to 118 mg/kg (15-30 cm), K rose from 35.62 mg/kg (0-15 cm) to 38.45 mg/kg (15-30 cm).

3.3 Hypotheses Testing

Ho₁: urbanization-related activities do not cause any significant change in the soil quality of the Port Harcourt metropolis between 2000-2020.

This hypothesis seeks to establish the impacts of urbanization-related activities on soil quality (cause and effect) in the area hence, a one-sample t-test was applied to the mean values of the parameters of the data in Table 5 (laboratory results for soil sample analysis).

Detail of the calculation is in the appendices while a summary of the result is presented here below.

Table 6. Summary of t-test calculation for Ho₁

t-cal.	Df	Sign. Level	t-critical	Decision
2.91	5	0.05	2.57	Ho ₁ Rejected

From Table 6 above, at the degree of freedom of 5, the calculated t was 2.91 while under the 0.05 significance level, the critical t is 2.57. Hence, the null hypothesis which stated that urbanization-related activities do not cause any significant change in the soil quality of the metropolis is hereby rejected while upholding the alternate hypothesis. This implies that urbanization-related activities cause significant changes in the quality of the soil in the area.

Ho₂: there is no significant difference in the perceived effects of pollution-induced soil-borne diseases on the socio-economic lives of residents in the area.

This hypothesis seeks to establish if there is any significant difference in the perceived effects of pollution-induced soil-borne diseases on the socio-economic lives of residents in the area hence, the one-sample chi square statistical tool was applied to the data.

A detail of the computation is presented in the appendices section while a summary is presented here below.

Table 7. Summary of χ^2 calculation for Ho₂

Cal. χ^2	Df	χ^2 -critical	Sign. Level	Decision
711.26	3	7.81	0.05	Ho ₂ Rejected

From Table 7, the calculated χ^2 of 711.26 is by far greater than the χ^2 critical value of 7.81 under a degree of freedom 3 of the 0.05 significance level hence, the null hypothesis which stated that there is no significant difference in the perceived effects of pollution-induced soil-borne diseases on the socio-economic lives of residents of the area is hereby rejected while the alternate hypothesis is upheld. In conclusion therefore, there is significant variation in the perceived effects of the diseases on the socio-economic lives of the people of the area.

4. Discussion of Findings

4.1 Urbanization-induced Activities and Soil Pollution in the Area

Objective 1: To examine the impacts of urbanization-induced land use activities on the soil quality status of Port Harcourt Metropolis

The result of the laboratory analysis indicated that certain land use activities (e.g. mechanic workshops, waste dumpsites) affect soil quality in the area. The pH level in the soil of the area ranges from 6.1 to 8.14 and has a mean occurrence of 7.22. While some of the soils indicated alkaline, others were neutral and a few others were acidic. In terms of spatial spread, soil pH value was 7.1 around Mile 3 mechanic village, 6.6 at the Eagle cement area, Abuloma, and NPA road; 7.3 at Nkpor; 5.9 at Egbelu; 6.8 at Mgboshimini Agip; 6.7 around Trans-Amadi; 6.4 around Old GRA/Forces Avenue; 6.5 in D/Line; 6.3 at GRA Phase 2; 7.7 around Rumuodara. The highest figure of 8.2 was recorded at Eneka while the least figure of 5.7 was recorded at Nkpor. Soil temperature is almost the same across the metropolis. It ranges from 24.31 to 26.10 °C with a mean of 25.6 °C. The highest values 25.57 to 26.10 °C occur around the central spot near Elekahia and Ogbonabli and the western flank near Rumuolueni and Mgbuosimini. Some of the sites with the highest temperature values include Ogbuosimini (26.1 °C), Egbelu (25.6 °C), and Eagle cement area (25.3 °C). The least value was recorded at mile 3 mechanic village.

Phosphorous (PO_4) values range from 0.010 to 0.629 mg/L and a mean of 0.342 mg/L. Some of the communities/sites with relatively very high figures include Mgbuosimini-Agip (0.63 mg/L), mile 3 mechanic workshop (0.47 mg/L), Rumuolueni (0.41 mg/L), Trans-Amadi 1. A (0.4 mg/L), Abuloma (0.38 mg/L), Rumuodara (0.38 mg/L) and Eneka (0.38 mg/L). Whereas some sites recorded the least values e.g NPA (0.02 mg/L), Nkpolu (0.10 mg/L), D/line (0.05 mg/L), GRA I (0.08 mg/L), Nkpor (0.02 mg/L), Egbelu (0.08 mg/L), etc.

Lead (Pb) mean occurrence level in the soils of the area is 120.62 mg/kg. Pb values range from 0.074-56.58 mg/kg west of the north-central, south-central around Ogbunabali and Eastern-by-pass; 56.58-79.51 mg/kg in most places stretching from north-west, west, north-north, and east in a ring of 79.51-108.17 mg/kg at the north-central and down south-south of the metropolis surrounding Borokiri and near Orakwo village at the western flank. It is within the range 108.17-149.94 mg/kg at the north-central and south around Aggrey and Finema.

The level of Potassium in the soil of the metropolis ranges from 34.19 to 89.57 mg/kg with a mean occurrence level of 66.81 mg/kg. The figures are higher (65-89 mg/kg) around the west, north and north-eastern parts; and low (50-55 mg/kg) around the east and southern parts; very low (34 – 50 mg/kg) around the most central part of the south. Nitrates level ranges from 0.001 to 3.30 mg/L with a mean of 1.65 mg/kg. At the extreme eastern, western and south-western areas, the values range from 0.00 to 0.68 mg/kg; 0.68 to 1.11 mg/kg at the centre around Eliozi, Rumuodara, Bori camp, and Oginigba, also at the west near eagle island, southern communities of Aggrey, old GRA; 1.11 to 1.38 mg/kg around most of the north, east, and west flank; 1.38 to 1.81 mg/kg at the west, east and south-eastern bloc; and between 1.8 to 3.30 mg/kg around the extreme south of the metropolis.

One striking fact about the soil analysis is that, in almost the 15 sampled points, most of the parameter values increase with an increase in depth from 0-15 and 15-30 cm. For example, while pH (7.1) was the same for mile 3 mechanic workshops, NO_3 in 2020 increased from 2.2 mg/kg (at 0-15 cm depth) to 6.3 mg/kg (at 15-30 cm depth). PO_4 rose from 0.29 mg/kg (0-15 cm) to 0.47 mg/kg (15-30 cm); Pb increased from 116.2 mg/kg (0-15 cm) to 118 mg/kg (15-30 cm), K rose from 35.62 mg/kg (0-15 cm) to 38.45 mg/kg (15-30 cm).

It is pertinent to state here that the result of the tested hypothesis (Ho_2) revealed that urbanization-related activities cause significant changes in the soil quality of the area. This study was able to examine the potential impacts of urbanization-related activities on soil quality within the metropolis. From the study, the soil quality of those areas nearer to waste dumpsites (e.g. Eagle cement road, Woji, East-west road axis of Rumuosi-Rumuekini and Alakahia, Mile 3 mechanic area, etc.) have higher values than the samples from other sites. Again, the soil structure and texture of the samples from those areas with heavy urban activities are looser and smaller in size than those at the fringes of the metropolis.

The finding of this objective is in line with earlier studies by Narayanan (2011) in his work “*environmental*

pollution: principles, analysis and control”; Ottoh (2019) in his study of “*the impact of deforestation on soil physicochemical properties in Andoni Local Government Area of Rivers State*”, noted that deforestation as a land use activity exposes the soil to the works of erosion and denudation and this results in changes in soil physicochemical properties; and Jaja (2020) in her work on “*the impacts of deforestation and soil physicochemical parameters in Ukwa East Local Government Area of Abia state*”, also noted that soils in forested areas are richer in soil nutrient and are of better quality than those from deforested lands.

4.2 Urbanization-induced Activities and Emergence of Soil Borne Diseases in the Metropolis

Objective 2: To find out the pollution-induced soil borne diseases that are prevalent in the area

This objective was also achieved. The study was able to determine the various pollution-induced diseases prevalent in the area, and their perceived effects on the socio-economic development of the people of the area. From the interactions with the residents and available hospital records, the commonest soil-borne diseases in the area include vascular witts (13%), Strongyloides stereoralis (14.9%), Ascaris lumbricoid (39%) and Trichuris trichiura (33.1%). Although, the occurrence of soil-borne diseases in the area does not pose a severe threat to public health like water-related and airborne diseases, it is important to checkmate their occurrences because of their potential effect on the socio-economic development of the people. The finding of this objective is in line with the works of Narayanan (2011) in his work “*environmental pollution: principles, analysis and control*”; and Amadi (2016) in his study on *disease burden and access to health care in Emohua and Ikwerre Local Government Areas of Rivers State*.

4.3 Perceived Effects of Emergence of Soil Borne Diseases in the Metropolis

Objective 3: To find out the perceived effects of the pollution-induced soil-borne diseases on the socio-economic development of the people of the area

Objective three was also actualized as the study was able to opine that the emergence of diseases in the area posed a significant threat to public health. It affects the socioeconomic lives of the people. However, the result of the tested hypothesis (Ho_2) revealed that there is a significant difference in the perceived effects of pollution-induced diseases on the socio-economic development of the people of the area. The people waste time and

resources (hard-earned income) treating ailments (especially, protracted sicknesses); and this affects their productivity and economic development. The finding of this objective corroborates with earlier postulations by other researchers. For instance, Amadi postulated that the poor environmental condition of most surroundings in Ikwerre Local Government Area leads to the emergence of soil-borne diseases ^[25].

4.4 Production of GIS-based Maps

Objective four was also achieved. The study was able to produce geo-spatial digitized maps of the soil pollution status of the area using GIS as shown in Figures 2 to 7. It is therefore one of the first attempts with a holistic overview of soil pollution in the area.

5. Conclusions

The study was able to do justice to all the stated specific objectives as they were all achieved; and the key findings were in line with previous studies. Urbanization-induced land use activities are causing significant changes in the soil quality of the area. The main urbanization-related land use activities causing changes in the quality of the soil of the area include: industrial manufacturing and processing, urban agriculture, domestic, mechanic workshops, soil waste disposal activities. Soil pollution causes the emergence of certain soil-borne diseases such as vascular witts, Strongloids stereoralis, Ascaris lumbricoid and Trichuris trichiura. These soil pollution-induced diseases affect the socioeconomic development of the people of the area. Based on the tested hypotheses, the stated null hypotheses were rejected at the 0.05 significant level of the chi square and t-test statistical tables. Specifically, urbanization-induced land use activities affect the quality of the soil of the metropolis (H_{01}); and there is a significant difference in the perceived effects of the diseases on the socioeconomic well-being of the people of the area (H_{02}). The laboratory results of the soil analysis revealed thus (mean values): pH 7.22, temperature 25.62 °C, PO_4 0.342 mg/kg, Pb120.62 mg/kg, K 66.81 mg/kg, NO_3 mg/kg.

Based on the findings of the study, the researchers concluded by recommending thus:

1) The state government should help in the enforcement of physical planning and development control laws; as well as imposing heavy taxes on developers to curtail the rate of outward growth the as well as an attempt to re-direct development to other parts of the state;

2) To reduce the impacts of urbanization-related activities on the soil quality of the area, all relevant

Agencies of government should ensure proper monitoring of land use activities including regular evaluation of the quality of the soil of the area;

3) Both government and the organized private sector should collaborate especially in the adoption and implementation of proactive measures and strategies aimed at controlling soil pollution in the metropolis such as restriction of certain land use activities which threaten soil quality to certain locations and under strict supervision (e.g. mechanic workshops, waste dumpsites, mineral mining and other industrial activities).

Limitations to the Study

The study was limited by a number of factors nevertheless. These limitations did not pose any serious effect on the outcome of the investigations as adequate precautions were taken to curb their effects. These limitations include funding of elaborate and comprehensive experimentations and wider scope; time factor; bureaucratic bottlenecks and secrecy on data gathering from hospitals and government ministries; etc.

Areas for Further Research

It is our suggestion, that there should be an expanded study to cover if possible, the entire urban space of Port Harcourt to include all the fringe areas as well as commercial/market centres, hospital premises, institutions, etc. Again, the government should fund a comprehensive study to include water, air, noise and other environmental factors around the metropolis.

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EDITORIAL

Mitigation of Climate Change: Too Little or Too Much

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Professor Emmanuel Epstein gave a conference entitled “Too little or too much” referring to plant nutrition and essential elements in 1990 ^[1], serves as a tribute to this professor emeritus, and this concept fits well with the actions related to the mitigation of Climate Change. After the 26th UN Climate Change Conference of the Parties ^[2] held in Glasgow under the slogan “UNITING THE WORLD TO TACKLE CLIMATE CHANGE”, it is time to reflect deeply on the subject and act.

Firstly, it is important to consider the recognition, explicit recognition, by The Intergovernmental Panel on Climate Change ^[3] that humanity drives and causes this climate change fact. It is obvious that throughout the Earth's history, the climate has changed as well as many extinctions ^[4] happened: i.e. Ordovician-Silurian (445 million years ago), Devonian (375 million years ago), Permian-Triassic (251 million years ago), Triassic-Jurassic

(205 million years ago), Cretaceous-Tertiary (65 Million Years ago) ... and are we inside the Holocene extinction?

Nowadays many authorized voices claim that we are under a new extinction period and climate is changing due to human actions. Are both directly associated or it is just a coincidence in time? Maybe, both are closely related but the starting point of these processes is not coincident. In this sense, as the effects are globally affecting the Earth and the biodiversity of the planet, it is supposed that we have to look for a global solution. Surely, the economy is under global rules but not law, social welfare and governance. Moreover, environmental resources and conditions are different in any geographical part of the world. The solutions to mitigate climate change are not global solutions because every region or country starts from very different economic and social situations. They have limited availability of resources, energy, water, food,

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... The first interest of a regional or local government is (maybe) to give support to their society by facilitating resources and trying to achieve social welfare. To reach this, it is necessary to know the regional geographical context.

The actions taken to mitigate, too little or too much depending on the (un-)desirable increment of the temperature of the planet to reach, should be studied and applied considering not only environmental parameters, but social and economical status at the regional and local scales and the availability of resources. However, one more issue should be considered, the sustainability. This word was first used in 1972 in the context of man's future^[5]. Mitigation and sustainability go together with the fact of reducing the negative effects of climate change and ensure our future.

Think globally, act locally, the idea attributed to Geddes (1915) applied to urban planning^[6], has a new dimension nowadays. In fact, understanding urban metabolism is the key to the future. At least it is expected that close to 70 % of the people live in urban areas by 2050 according to United Nations Population Division^[7] when nowadays this percentage is over 56%^[8]. In developed countries this percentage is over 75%. Cities are great consumers of energy, food and resources and produce a great impact on the environment and climate change and cities should adopt strategies for sustainability^[9].

From Geography and Environmental Sciences, we have to act after a thorough review of the local and regional situation, social, economic and environmental parameters, adapting the possible actions to the closest environment.

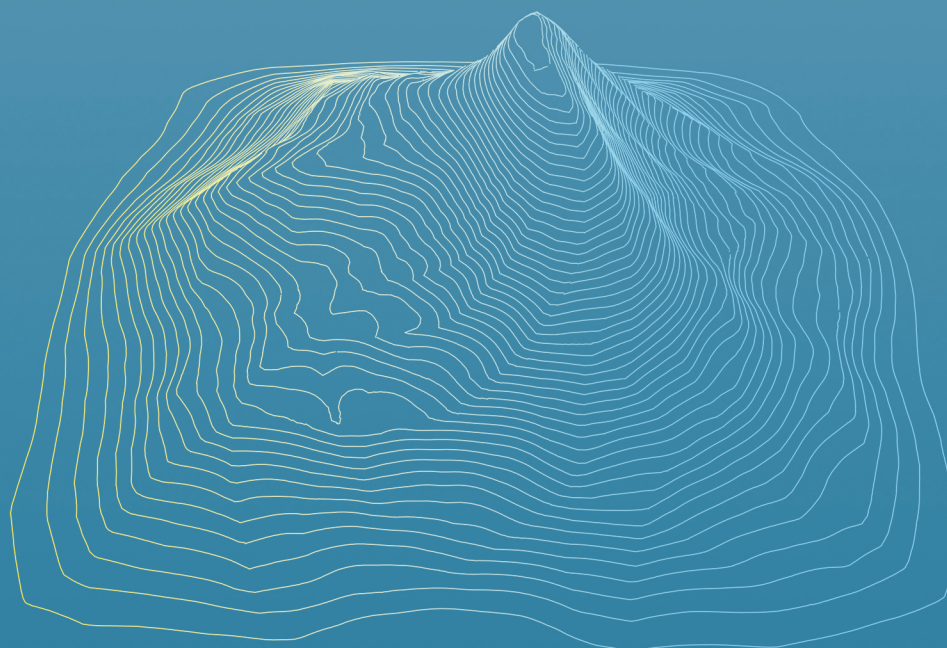
The available resources, responsibility and possibilities to contribute to a major reduction of climate change impact correspond to the developed countries. There are great differences between developed countries and developing countries. First, the great contribution of developed countries like USA, European Union, Russia or China to climate change and, second, the technological possibilities and economic resources to adopt sustainable and environmentally friendly solutions to mitigate Climate Change.

This journal wants to serve as a framework to show the local and regional actions to mitigate the negative effects,

to understand the consequences of these actions from a global point of view and promote the dissemination of knowledge that can serve so that the objective of reducing the negative effects of climate change is the maximum. It is never too much when it comes to securing our future.

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