EFFECTS OF SEASONALITY ON ACCESS TO IMPROVED WATER IN BENUE STATE, NIGERIA

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Abstract

Many people switch sources of drinking water and sanitation between seasons, yet such shifts are not reflected in the reporting of access to improved water and sanitation services by the Joint Monitoring Programme (JMP). Drawing on quantitative and qualitative data collected from urban and rural sites in dry and rainy seasons in Benue state Nigeria, this study highlights the importance of seasonal variations in water access and quality. Water testing showed that water sources had higher levels of contamination with coliforms, nitrate and chloride in the dry season than the wet season. The contamination of water from these pollutants are above WHO standards and believed to come mainly from pit latrines. Semi-structured interviews revealed that many people who use improved water and sanitation facilities in the rainy season sometimes switch to poorer quality unimproved sources in the dry season. Travel times for collecting water as well as waiting times also significantly increased in the dry season. It is recommended that this important seasonality element is factored into JMP data collection and reporting.

Key words: Access, Benue State, Improved Water, Seasonality, Nigeria

Introduction

Sustainable Development Goal 6 (SDG6) sets out to achieve universal access to safe, affordable drinking water and achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations by 2030 (WHO and UNICEF 2015). Monitoring access to water and sanitation (watsan) and tracking progress towards SDG6 is an important activity for the Joint Monitoring Programme with the key indicator being the proportion of population using safely managed drinking water services and sanitation (WHO and UNICEF 2017). Safely managed water is defined as an improved water source[1] which is located on premises, available when needed and free from faecal and priority chemical contamination. The JMP methodology stated that the microbial standard applied is there should be no E. coli detection in a 100ml sample. An accepted alternative is the presence of thermotolerant coliforms. Priority chemical contaminants monitored at the global level are arsenic and fluoride. Generally, the JMP collects data on compliance based on respective national standards and WHO guideline values of 10 μg/L for arsenic and 1.5 mg/L for fluoride (JMP Methodology 2018). As part of SDG6 monitoring, the JMP aims to test for water quality at the points where users collect water.

Chloride and nitrate are also important pollutants in groundwater and so also considered here. Chloride originates from rocks, sodium in drinking water, mineral dissolution, industrial and domestic waste. Their effects are deteriorating plumbing, water heaters, municipal water equipment and taste (Garbarino, Struzeski et al. 2002). It also comes from fertilizers and faeces (Wright, Cronin et al. 2013). Graham and Polizzotto (2013) noted that after nitrate, chloride is the most commonly investigated chemical indicator of groundwater contamination from latrines due to its high concentration in excreta and its mobility in the subsurface. Chloride is transported during groundwater flow with minimal retention and sometimes found alongside nitrate (Banks, Karnachuk et al. 2002). The effects of chloride in water is that it reacts with organic matter to form trihalomethanes, notably chloroform $CHCl_3$ which is a suspected liver carcinogen in humans. Other health effects are eye/nose irritation, stomach discomfort and increased corrosive nature of water (Fewtrell 2004).

Nitrate comes from agricultural activities, such as run-off from fertilizer use and from animal and human faeces, in the form of leakage from septic tanks, sewerage and from erosion of

[1] WHO/UNICEF (2015) defined 'improved' drinking water sources as 'ones that by the nature of their construction or through active intervention are protected from outside contamination, in particular from contamination with faecal matter'

natural deposits. Ahmed, Khandkar et al. (2002); Pedley, Yates et al. (2006) and Fourie and Van Ryneveld (1995) consider nitrate as a common chemical issue from onsite sanitation systems. High concentrations of nitrates can cause health concerns. Such effects are mostly on infants below the age of six months. Symptoms include shortness of breath and blue baby syndrome (Patil, Sawant et al. 2012, Moyo 2013). The WHO guideline for nitrate is 50mg/l. Higher rates of nitrates give rise to methaemoglobinaemia in young children. Graham and Polizzotto (2013) reported nitrate contamination to be active in rainy and sandy soil conditions. Researchers such as Zingoni, Love et al. (2005); Tandia, Diop et al. (1999); Vinger, Hlophe et al. (2012); Wright, Cronin et al. (2013) have linked nitrates with contamination from pit latrines. To address the impacts of poor sanitation on water quality. the JMP has placed recent emphasis on safely managed sanitation. This refers to the use of an improved sanitation facility[2] which is not shared with other households, and where excreta are safely disposed in situ or transported and treated offsite (WHO and UNICEF 2017).

Kostyla, Bain et al. (2015) in their systematic review reported that most studies found greater drinking water contamination in the wet than dry season. They linked this to the possibility of more pollution loading in urban environments due to high population and high latrine usage (Isunju, Schwartz et al. 2011) and movement of effluents in the wet season due to abundance of water and rising water table levels (Kiptum and Ndambuki 2012). Again, Kiptum and Ndambuki (2012) noted that the higher the number of well users, the higher the amount of water drawn from a well and the amount of water discharged into the latrines. As more water is drawn from wells, there is a hydraulic gradient between the well and latrine which induces water to flow into the wells and consequently create contamination. Godfrey, Timo et al. (2006)

[2] WHO/UNICEF (2015) defined an ‘improved’ sanitation facility as ‘one that hygienically separates human excreta from human contact

also reported that contamination from wells could be greater in the dry season due to higher usage rates which contaminate water in the withdrawal process.

In collecting data and reporting on access to improved water and sanitation, the JMP emphasises the main source of drinking water and sanitation facilities which may mean that data on secondary sources may be missed. Also, as monitoring is normally carried out every five years, important seasonal changes in the nature and quality of water sources and sanitation systems are not reflected in data collection and reporting. Although monitoring under SDG6 tracks the use of improved water sources and has incorporated normative human rights criteria including accessibility, availability and quality, the drinking water technologies classified as 'improved' remain broadly the same. This has resulted in critiques of a lack of temporal sensitivity within SDG monitoring (Satterthwaite 2016) which can result in underestimates in access to safely managed drinking water and sanitation. More importantly, health risks associated with faecal contamination may be underestimated if sanitation system monitoring or water quality testing misses important seasonal variations (Kostyla, Bain et al. 2015, Kumpel, Cock-Esteb et al. 2017, Jewitt, Mahanta et al. 2018, Dongzagla, Jewitt et al. 2020). The extent to which drinking water source quality varies seasonally and geographically represents an important gap in the literature with a range of conflicting findings arising from the limited number of studies that have investigated this (Kostyla, Bain et al. 2015).

Seifert-Dähnn, Nesheim et al. (2017), Kithuki, Opanga et al. (2021) maintained that seasonal changes occur in the type of drinking water people use, mainly due to water scarcity during the dry season. Because of this, people who state that their main water supply is tap water may use surface water for a significant proportion of the year. Changes in water quality are frequently observed with shifts in water supply sources with seasonal differences in water quality being widely observed. In their study in India, Seifert-Dähnn, Nesheim et al. (2017) reported that only 49% of households consumed drinking water that satisfied the criterion of no faecal coliform detection in 100ml samples during the post monsoon season. In the pre-monsoon season, the percentage dropped to 40% and to 36% during the monsoon season. The varied findings from these different studies highlights the importance of obtaining better and more geographically sensitive understandings of seasonal and spatial variations in sanitation and drinking water access and quality in order to inform future monitoring strategies in different areas. In order to contribute to such understandings, this paper takes a mixed methods approach to explore seasonal and spatial variations in water and sanitation use and quality within nine study sites located in the greater Makurdi and Konshisha areas of Benue state, Nigeria. The objectives of the study were to: Determine when previous sanitation and drinking water monitoring has been carried out in relation to seasonality, identify seasonal differences in measured and perceived water quality, explore respondents' perceptions of water quality and identify key causes of drinking water source contamination.

The paper's significance and originality stems from the attention it draws to seasonal and spatial variations in watsan access and quality and the human health implications of this for regions exhibiting a high degree of seasonality. We argue that in such areas there is value in considering the influence of seasonality when designing watsan testing schedules to detect fluctuations in their quality and functionality. Such approaches are important for avoiding overestimates of access to safely managed water and sanitation and have implications for monitoring progress towards SDG targets in Nigeria and beyond. Our findings are likely to be of interest to practitioners, policy makers and academics with interests in watsan access, quality and associated health impacts in low and middle-income countries.

Methodology

Study Area

Benue State is located within the coordinates of Latitude 6^0 25^1 and 8^0 08^1 north of the Equator and Longitude 7^0 47^1 and 10^0 00^1 East of the Greenwich Meridian (figure 1). The state, like most others in the middle of the country experiences dry and rainy seasons. The rainy season starts in April and ends in October while the dry season starts in November and ends in March.

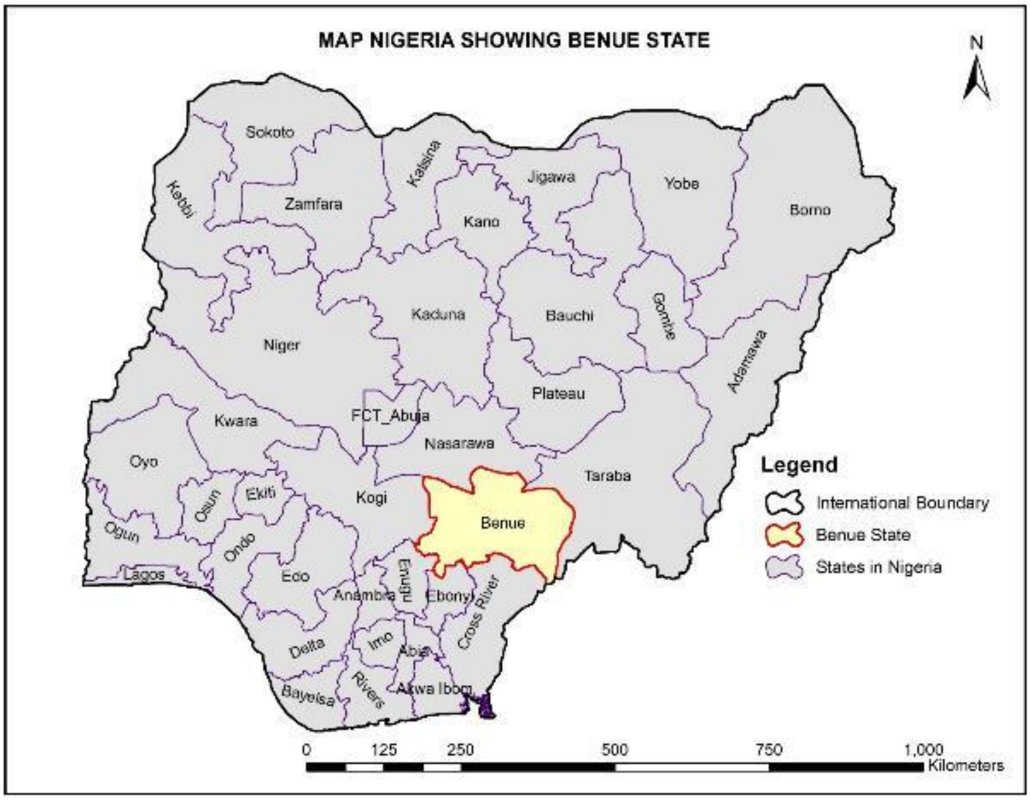

Figure 1: Nigeria showing Benue state
Source: Digitised from Google map

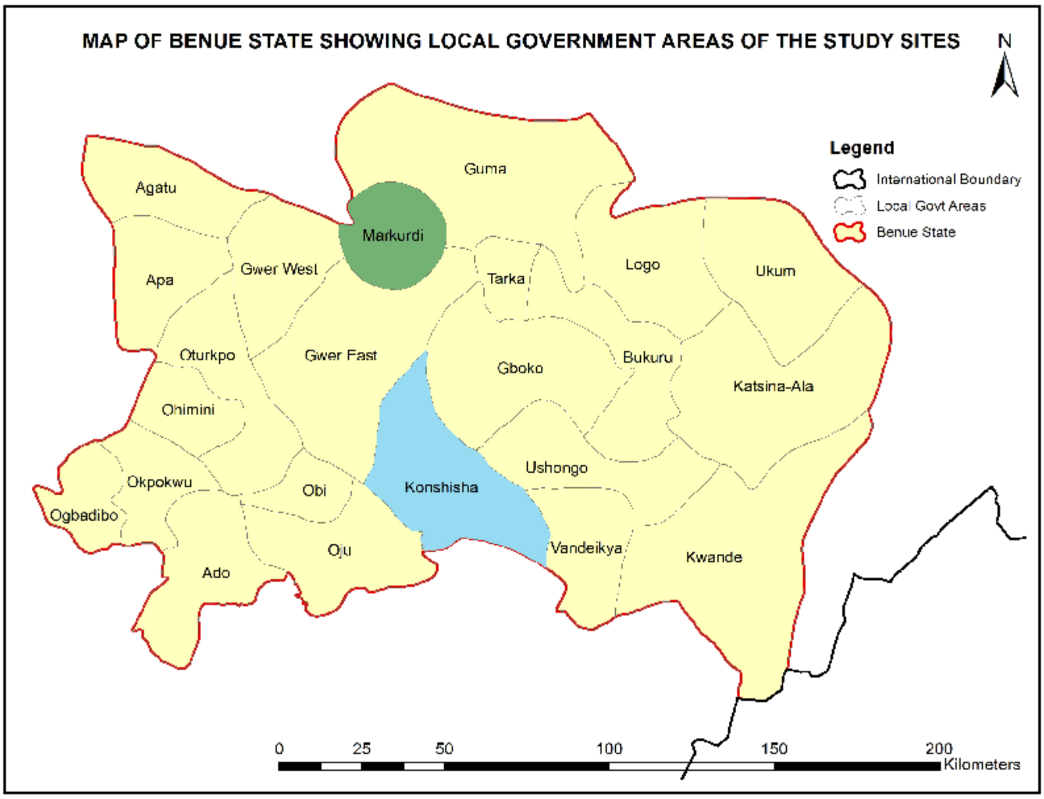

Figure 2: Benue state showing the study areas
Source: Digitised from Google Map

Benue state also shares a small section of the Nation's international boundary with the republic of Cameroon to the South East of the state.

According to the 2006 population census, Benue State had a population of 4,253,641 million people. The dominant ethnic groups are Tiv, Idoma and Igede. The main sources of water for drinking are dug wells, boreholes, surface water, rainwater and tap water. While tap water is mostly available only in the urban areas, the other sources are also used in the rural areas. In the dry season, boreholes are mostly used in the urban areas while in the rural areas, boreholes and surface water are mostly used. The main sanitation sources are 'pour flush' toilets while traditional pit latrines are more common in the rural areas. Makurdi is Benue State's capital and five sites within the 16 km radius of the town known as 'greater Makurdi' were selected for study comprising of High Level, Wurukum, Wadata, North Bank and Kanshio. The urban study sites such as Wadata and North Bank are characterised by waste littering. The second study site was located in Tse-Agberagba which is the local government headquarters of

Konshisha. This site is predominantly rural and was selected to contrast with greater Makurdi which is located approximately 75km away and experiences the same seasonal weather patterns. The Catholic church divided Tse-Agberagba into four zones (Alemenyi, Dam, Konshisha and Secretariat) which were used as data collection sites.

The town's economy relies heavily on agrarian activities, and crops produced in large quantities include yams, groundnuts, maize, guinea corn, rice, cassava, bambara nuts, while citrus crops (mainly oranges) are also produced in large quantities. Tse-Agberagba has recently been connected to the power supply and its major water sources are wells, boreholes and streams. There is also an earth dam which is the main source of water supply in the area during dry season. Water is very scarce in this season as most of the wells dry up, forcing a shift to the use of boreholes and water from rivers. The major sanitation facilities are 'pour-flush' toilets and traditional pit latrines.

The study design used a mixed method approach. Baseline data from the Nigerian Demographic and Health Surveys (DHS) were used to provide information on key trends in water and sanitation access and to inform the development of the research and interview questions. Water samples were taken from wells and tested for microbial and chemical parameters. Perceptions of water quality were obtained from semi-structed interviews with respondents, totalling 40, thereby enabling the incorporation of both qualitative and quantitative methods. The study received ethical approval from the University of Nottingham. All respondents were provided with information on the nature of the study, asked to sign consent forms and informed that their participation was voluntary, and they could withdraw at any time if they wished.

Baseline data from DHS surveys

The DHS data analysed was collected during surveys undertaken in 1999, 2003, 2008, 2010, 2013, 2015 and 2018. The DHS runs two types of surveys: standard and interim. The standard surveys have a large sample size (between 5,000 and 30,000 households) and are normally conducted every five years so that comparisons between surveys can be made. Interim surveys do not cover comprehensive impact evaluation measures but are based on key performance monitoring indicators between rounds of surveys. They are nationally representative like standard surveys but have smaller samples and shorter questionnaires. Both types of survey feature questions regarding access to water sources and sanitation and although water testing will in time form part of tracking progress towards SDG6, this was not undertaken at the time of the surveys analysed here.

Significantly, however, the timings of the different DHS surveys are not directly comparable in terms of seasonality as they took place at different times of the year. The rainy season in the study area starts in April and ends in October while the dry season starts November and ends in March. The 1999 survey took place in the dry season between 29 March and 29 May 1999 while the 2010 survey ran from October through December 2010, much earlier in the dry season. Fieldwork for the 2013 survey was conducted from February 15, to the end of May 2013; between the end of the dry season and the start of the rainy season while the 2018 NDHS took place between 14 August 2018 and 29 December 2018, starting in the rainy season but finishing in dry season. The non-comparability of the seasons is a gap addressed by one of the paper's objectives.

Water quality testing

Water was tested from both improved and unimproved wells in both urban and rural sites in dry and wet seasons. The improved/unimproved well categories are based on the JMP's definitions as earlier mentioned and in the study area relate mainly to protected and unprotected wells. These categories are based on longstanding JMP definitions (WHO/UNICEF 2015) and, as recognised in more recent definitions (WHO/UNICEF 2021), do not necessarily reflect the actual quality of water obtained from these sources.

Data for water quality tests was collected from 100 wells: 50 in the urban sites within greater Makurdi and 50 in the rural sites within Tse-Agberagba. All these wells were tested during the rainy season (October 2016) and then again in the dry (March 2017) season. At the time that the water samples were taken, data were also collected on associated well characteristics. The sample size of 100 wells across the sites was taken to allow statistical tests to be undertaken (Pallant 2016) and because most of the reagents were available in packs of 100s. Furthermore, this number reflected available resources within the fieldwork budget.

The inclusion criterion for the water quality tests was that the wells chosen were in the same compounds as pit latrines. Therefore, houses without wells, those with water closets, wells in different compounds to latrines and houses with wells but without pit latrines were excluded from the sample.

Water samples from dug wells were collected using sterile bottles and kept in a cooler. These were taken to the laboratory immediately for analysis. The bottles were carefully opened and rinsed with the sample twice before water collection. Care was taken not to contaminate the samples in the process of collection. The fact that the control samples tested negative confirms that the samples were collected carefully and without contamination.

Tests for faecal coliforms were undertaken using 3M Petrifilm Aqua Coliform Count Plates (AQCC). AQCC is a sample ready culture medium system which contains Violet Red Bile (VRB) nutrients, a cold-water soluble gelling agent, and a tetrazolium indicator that facilitates colony enumeration and is used for the enumeration of coliforms in the bottled water industry. On the 3M petrifilm Aqua AQCC plates, coliform colonies are indicated by red colonies associated with gas. Gas trapped around red coliforms colonies indicate confirmed coliforms, eliminating the need for a subsequent confirmation step (Petrifilm 1999). From each sample of water, 1ml was placed on a petrifilm, stacked and incubated for 24 hours for total coliforms. The developed colonies were counted and recorded for analysis with comparisons being made between samples collected during the dry and rainy seasons.

Coliforms counts are generally grouped to make more meaning of the data based on the risks posed. In this research the coliform forming units (cfu) per 100ml were classified into 0 or <1 (no risk), 1-10 (low risk), 11-100 (high risk) and over 100 (very high risks) (Jensen et al., 2004; Gundry et al., 2004; Gundry et al., 2006; Brown et al., 2008b). The reliability of petrifilm has been reported elsewhere (Beloti, Souza et al. 2003, Nelson, Feazel et al. 2012, Murcott, Keegan et al. 2015, Dongzagla, Jewitt et al. 2020).

Tests for nitrate and chloride were undertaken by using tablets and colour matching as described by the manufacturers. The palintest tablets were diluted into 10 ml water samples and shaken. The solution could stand for 10 minutes before using the colorimeter to match the colour against the graduated values.

The Man-Whitney U test was employed to test for differences in faecal coliforms between dry and wet seasons and for urban and rural variation in chloride contamination. It was also employed to test for nitrate in improved and unimproved wells plus rural and urban wells in both the dry and wet seasons. This test was adopted because it tests for differences between two independent groups on a continuous measure. The Kruska-Wallis test was used to test for nitrate and chloride among the sites in dry and wet seasons.

Qualitative data from household respondents

Qualitative data were obtained from semi-structured interviews with members of twenty households in each of the urban and rural sites: mostly with the heads of households but also with married women with responsibility for fetching water. Forty respondents were interviewed in total across the rural and urban sites. Interviews were also held with staff from government agencies including Benue State Sanitation Authority, Ministry of Water Resources and Environment, Benue State Water Board and Benue Rural Water Supply and Sanitation Agency (BERWASSA). In addition, notes were made from observations on seasonal access to water, especially sources used and collection times. These observations included water purchased from water vendors in the urban sites, dry wells, queues at boreholes, collection of water from the dam and observations of different forms of water haulage in the rural sites.

Qualitative data obtained from recorded interviews were transcribed and entered into Nvivo version 11 pro for Windows to assist with the organisation of the data for easy retrieval. The data were then coded into the software at nodes and sub-nodes based on rural-urban categories and other major water and sanitation themes such as well water contamination awareness and major environmental problems.

Water Quality Results

Microbial Results:

Seasonal microbial results

In terms of seasonal variation in contamination with faecal coliforms, there was a statistically significant difference between dry and rainy seasons according to the Mann-Whitney U test with $Z=-4.62$, $p<.001$, with a medium effect size ($r=.33$). The median score on total counts decreased from the dry season (md=94) to the wet season (md=73.5) indicating that there was higher contamination of faecal coliform in wells in the dry compared to the rainy season.

In both the dry and rainy seasons, drinking water was heavily contaminated with faecal coliforms, but the dry season tended to be more highly contaminated than the rainy season as 93% of samples (compared to 81% in the rainy season) fell into the ‘very high’ category which equates to over 100 cfu/100ml water (figure 3). As the WHO guideline for faecal coliform is <1 cfu/100ml of water, all samples far exceeded this.

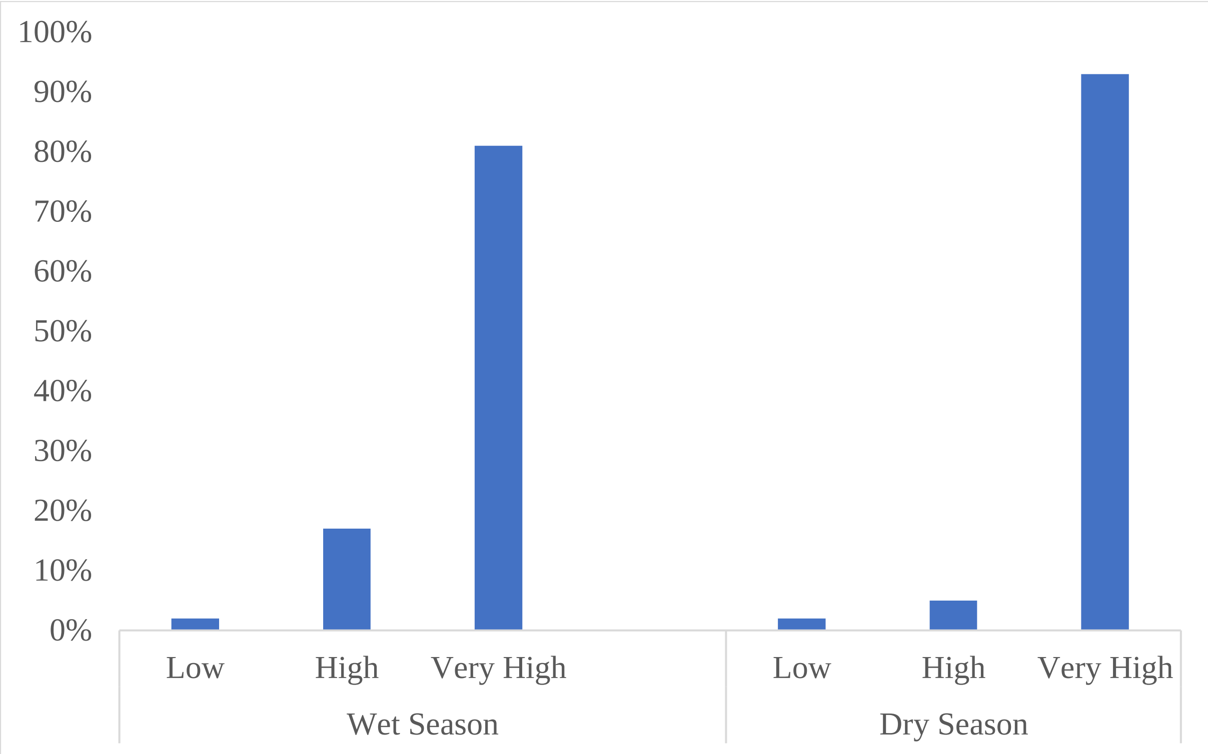

Figure 3: Rainy and dry season Coliforms for Benue State
Source: Field work 2017

Microbial Results for the Rural and Urban Samples

From figure 4, which is based on rainy and dry season faecal coliform data, both urban and rural sites were heavily contaminated, but faecal coliform counts were higher in the urban sites with 95% of the samples falling into the very high category compared with 67% in the rural sites. In the dry season, the rural sites were more contaminated (95%) compared with urban sites (92%).

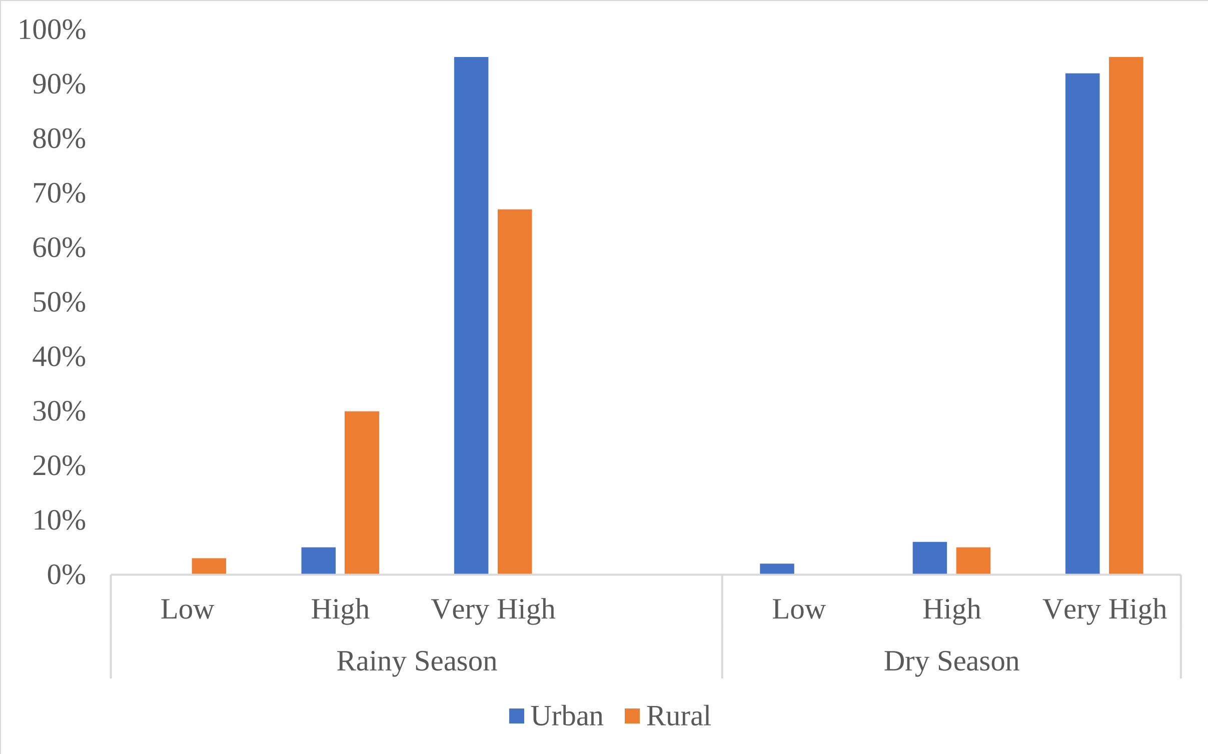

Figure 4: Rainy and dry season Coliforms for urban and rural sites in Benue State
Source: Field work 2017

Microbial results by Improved/Unimproved Water Source

Improved and unimproved well samples in the rainy season were both heavily contaminated although there were slightly more unimproved wells (82.8%: 51.4% urban and 31.4% rural) than improved wells (80%: 46.2% urban and 33.8% rural) that fell into the very high coliform count category. Similarly, in the dry season, 97% of unimproved wells fell into the 'very high' category compared with 92% of improved wells (figure 5).

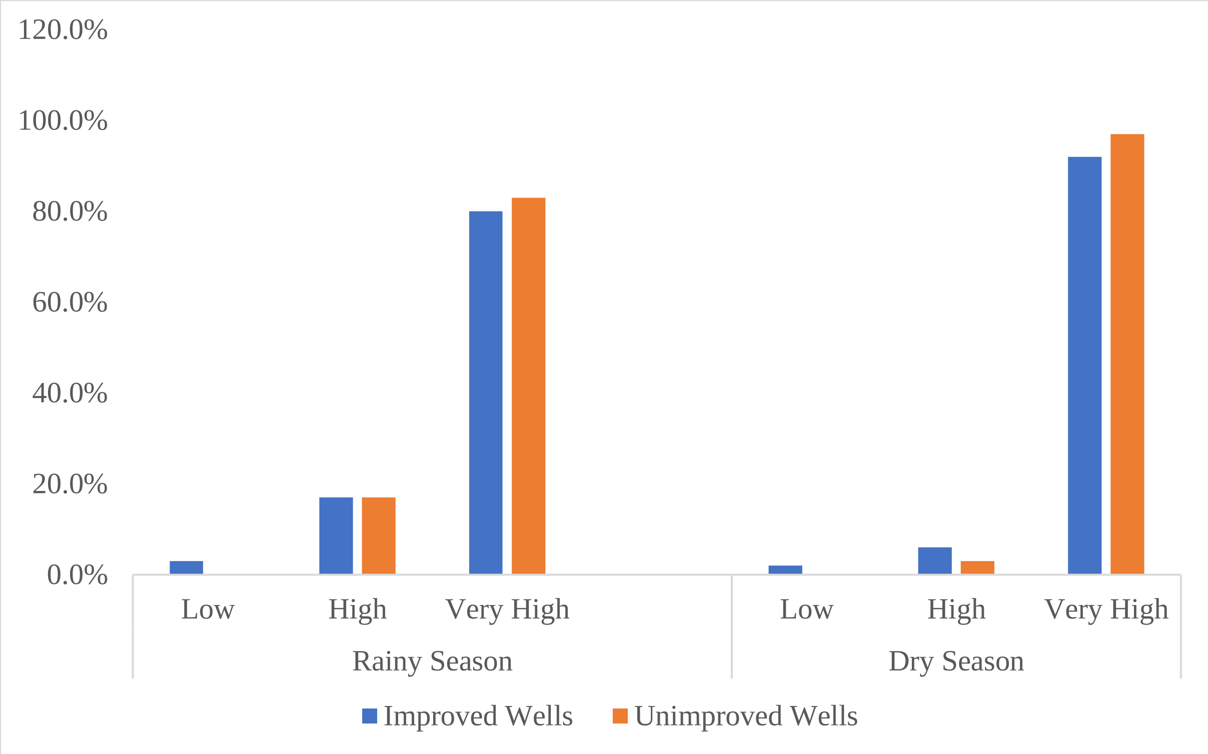

Figure 5: Improved/Unimproved faecal coliforms in rainy/dry season in Benue State.
Source: Field work 2017

Chemical Tests Results:

Nitrate Test Results

Although Nitrate is not mentioned among the priority contaminants, it was also investigated in this study due to its indication in faecal contamination. The Mann-Whitney U test showed no significant difference in nitrate contamination between improved and unimproved wells in the rainy season. The values for nitrates in the study sites are presented in table 1 and table 2. The WHO guideline for nitrate is that it should not exceed 50mg/l, yet this value was exceeded in three of the urban sites.

Table 1: Mean Dry and Wet Season Nitrate (mg/l) values for Urban Sites

Season	Site	Mean	Standard Deviation
Dry	HL	44.00	28.29
Wet	HL	46.64	20.97
Dry	KS	27.72	25.07
Wet	KS	47.52	23.45
Dry	NB	30.36	30.94
Wet	NB	66.00	0.00
Dry	WD	62.04	12.52

Wet	WD	59.84	19.48
Dry	WK	10.12	7.77
Wet	WK	29.04	20.97

Source: Field work 2017

As can be seen from the table above, the nitrate values were mostly higher in the rainy than the dry season as reported by other researchers.

Table 2: Mean Dry and Wet Season Nitrate (mg/l) Values for Rural Sites

Site	Season	Mean	Standard deviation
AL	Dry	16.50	17.61
AL	Wet	13.56	8.28
DM	Dry	10.27	10.50
DM	Wet	39.23	19.36
KSH	Dry	10.63	7.38
KSH	Wet	21.63	13.33
ST	Dry	31.89	33.55
ST	Wet	30.49	22.07

Source: Field work 2017

Similarly, in the rural sites, the values for nitrate were higher in the rainy than the dry season. This could be due to a rise in the water table and accelerated dilution and transport of chemicals in the ground in the rainy season compared to the dry season.

The Kruskal-Wallis test results showed that there were statistically significant differences in nitrate between the urban dry, urban wet, rural wet samples and between dry and wet seasons, but not in the rural dry season. In the urban dry and wet seasons, Wadata had higher nitrate levels. In the rural dry and wet seasons, Secretariat and Dam respectively had higher concentrations. The sites with higher concentration were also reflected in the higher median scores (table 3).

Table 3: Kruskal-Wallis Summary Table for Nitrates (mg/l)

Sites and seasons	Chi-square	df	n	Sig. level	Mean Rank
Urban sites in the dry season	16.94	4	50	.002	66.00 (WD)
Urban sites in the wet season	17.57	4	50	.001	66.00 (WD)
Rural sites in the dry season	2.49	3	50	.48	11.00 (ST)
Rural sites in the wet season	14.95	3	50	.002	35.20 (DM)

Source: Field work 2017

There was a statistically significant difference in nitrate contamination levels between the dry and rainy seasons according to the Wilcoxon ranked test: $z=-4.74$, $p<.001$, with a medium effect size ($r=.34$). The median score on nitrates increased from the dry season (md=11) to the rainy season (md=35.2). Nitrates levels were therefore higher in the rainy than the dry season.

In the test, m=median, n=number of cases in each group, u=Mann-Whitney U value and z= standardized test statistics, p=significant value (if it is less than .05, it is significant, otherwise, it is not) and r= the effect size, which is not given but calculated as r=z/square root of N, where N= total number of cases. Generally, the criteria of .1=small effect, .3=medium effect, .5=large effect.

In the improved and unimproved wells in the dry season, nitrate results showed that there was no statistically significant difference in nitrate contamination between improved and unimproved wells, although unimproved wells had a higher median value. That means unimproved wells were more contaminated. Higher contamination from unimproved than improved wells have been reported by other researchers.

Between urban and rural wells in the dry season, the Mann-Whitney U test revealed that there was a statistically significant difference in nitrate contamination between rural and urban wells with the latter having higher contamination levels. As there is a statistically significant difference between urban and rural nitrate levels, the median value in the urban sites is higher due to its higher nitrate concentration. This could be due to poor sanitation systems with higher population concentrations in the urban areas, especially from nitrogen loading in latrines.

Similarly, in the rainy season, the urban and rural wells test results from the Mann=Whitney U test showed that there was a statistically significant difference (since .000 is less than .05) in nitrate contamination between rural and urban rainy season wells. The Mann-Whitney U test statistics are summarised in the table below. For a recap, md1, n = median and number of cases in the first category; md2, n = median and number of cases in the second category; U = Mann-Whitney U value; z = standardised test statistics, p = significant value and r = the effect size.

Table 4: Mann-Whitney U Summary Table for Nitrates (mg/l)

Nitrates	Md1, n	Md2, n	U	z	p	r
Improved and unimproved wells in dry season	Improved md=17.6, n=65	Unimproved Md=112, n=35	1098	-3.0	.77	.03
Improved and unimproved wells in wet season	Improved Md=35.2, n=65	Unimproved Md=35.2, n=35	1077	-4.5	.65	.04
urban and rural wells in the dry season	Urban Md=26.4, n=50	Rural Md=8.80, n=50	801	-3.22	.001	.03
urban and rural wells in wet season	Urban Md=66, n=50	Rural Md=17.6, n=50	589	-4.67	.000	4.7

Source: Field work 2017

Chloride Test Results

Chloride is also not mentioned among the priority contaminants by the SDGs, but it is included here due to its link with faecal contamination. The study sites were significantly contaminated by chloride which suggest high risks from drinking such water. The respondents also mentioned the salty nature of water during semi-structured interviews, indicating high potassium chloride content. The chloride values are presented in table 5 and table 6.

Table 5: Mean Dry and Wet Season Chloride (mg/l) values for Urban Sites

Season	Site	Mean	Standard Deviation
Dry	HL	80.00	63.25
Wet	HL	50.00	52.70
Dry	KS	80.00	42.16
Wet	KS	40.00	51.64
Dry	NB	100.00	47.14
Wet	NB	100.00	47.14
Dry	WD	140.00	51.64
Wet	WD	110.00	73.79
Dry	WK	140.00	117.38
Wet	WK	210.00	228.28

Source: Field work 2017

It can be seen from the table above that values of chloride were very high in the study sites. There appear to be higher values of chloride in the dry season in some locations. Chloride levels were generally higher in Wurukum as only one sample (sample 8) had 0mg/l of chloride in the dry season. The levels were also higher in Wadata and North Bank areas with High Level and Kanshio having lower levels of concentration as eight samples each had 0mg/l chloride. Although there are no WHO health-based guidelines, excess chloride can give taste to water and indicate the presence of other substances. Since chloride is linked with waste the sites with high chlorides corresponded to areas with more waste and dirty surroundings.

Table 6: Mean Dry and Wet Season Chloride (mg/l) Values for Rural Sites

Site	Season	Mean	Standard deviation
AL	Dry	100.00	0.00
AL	Wet	16.67	38.92
DM	Dry	83.33	38.92
DM	Wet	0.00	0.00
KSH	Dry	75.00	45.23
KSH	Wet	0.00	0.00
ST	Dry	89.91	25.66
ST	Wet	4.05	10.30

Source: Field work 2017

Generally, chloride values appeared to be lower in the rural than urban sites. In the dry season, the values of chloride had been consistently 100mg/l while in the rainy season almost all sites had 0mg/l chloride apart from Alemenyi where sample five and twelve had 100mg/l chloride. It appears that rural sites in the dry season had more risk in terms of chloride concentrations. Many researchers reported that well water quality in the dry season may be affected by usage rates. They explained that as they are fewer sources of water to depend on in the dry season, the rate of contamination increases due to contamination from the materials used to draw water, especially for unimproved sources. In the study sites too, in the dry season, there are few water sources, and this puts a lot of pressure on them. This conforms to respondents’ complaints about water being salty in the dry season.

The Kruskal-Wallis test was employed to statistically analyse chloride among the sites and seasons. The test revealed that there was no statistically significant difference in chloride contamination among the urban sites in the dry season, rural sites in the dry season and rural sites in the rainy season. Chloride was only statistically significant in the urban sites in the wet season. Higher chloride values were recorded in North Bank and Wadata, corresponding to environmentally challenging sanitation sites. Details of the results and their corresponding mean ranks are found in table 7.

Table 7: Kruskal-Wallis summary table for chloride (mg/l)

Sites and seasons	Chi-square	df	n	Sig. level	Mean Rank
Urban sites in the dry season	7.90	4	50	.095	100.00 (ALL)*
Urban sites in the wet season	16.61	4	50	.002	100.00 (ALL)*
Rural sites in the dry season	6.35	3	50	.10	100.00 (ALL)*
Rural sites in the wet season	6.47	3	50	.09	00.00 (ALL)*

Source: Field work 2017. *Means all the locations had same mean rank

In terms of seasonal variations, the Wilcoxon test showed a statistically significant difference between the dry and rainy seasons, with the dry season having higher contamination: Z=-5.66, p<.001, with a medium effect size (r=.40). The median score on chloride in the dry season decreased from md=100 to md=0.00 in the rainy season. As mentioned earlier usage in the dry season tends to increase contamination rates.

Chloride was tested in both improved and unimproved wells in the urban sites in the dry season. The study sites were significantly contaminated by chloride which suggest high risks from drinking such water. The Mann-Whitney test was employed to compare chloride contamination between improved and unimproved wells in the dry season. The test revealed that there was no statistically significant difference in chloride contamination between improved and unimproved wells. Echoing research carried out elsewhere in the literature, both improved and unimproved wells had the same median value meaning that contamination levels were broadly the same. The Mann-Whitney U test showed that there was no statistically significant difference in chloride contamination between improved and unimproved wells in the rainy season. Furthermore, both improved and unimproved wells had the same median scores.

In terms of variations in chloride levels and mean values between rural and urban wells in the dry season, the Mann-Whitney U test showed no statistically significant difference. The Mann-Whitney U test did however indicate a statistically significant difference (since .000 is less than .05) in chloride contamination between rural and urban rainy season wells. Therefore, chloride values were significantly higher in urban compared to rural sites in the rainy season. This could reflect high nitrogen loading from sanitation systems from dense urban populations.

Table 8: Mann-Whitney U summary table for chloride (mg/l)

Chloride	Md1, n	Md2, n	U	z	p	r
Improved and unimproved wells in dry season	Improved md=100, n=65	Unimproved Md=100, n=35	1033.5	-1.078	.28	.11
Improved and unimproved wells in wet season	Improved Md=00, n=65	Unimproved Md=00, n=35	1094.5	-.36	.72	.04
urban and rural wells in the dry season	Urban Md=100, n=50	Rural Md=100, n=50	1120	-1.29	.20	.13
urban and rural wells in wet season	Urban Md=100, n=50	Rural Md=00, n=50	392	-6.90	.000	.69

Source: Field work 2017

Local perceptions of seasonal differences in water supply and quality

Findings arising from questions on whether and how access to and use of different water sources varies seasonally indicated that in the rainy season, drinking water options are more varied. In areas with access to tap water, respondents noted that it flows better during the wet season while in areas without tap access, rainwater harvesting is widely practiced by people with suitable collection and storage containers. Respondents also noted that they relied more heavily on natural (as opposed to processed) water sources such as water from dug wells during the rainy season. This leads to seasonal differences in the 'stacking' of water sources (Jewitt, Mahanta et al. 2018); a phenomenon largely neglected by DHS survey questions which ask about respondents' 'main source' of drinking water. The importance of this lies in the fact that people do not drink as much well water during the rainy season because they make greater use of rainwater. As one respondent from High Level area, noted:

> "It is the dry season that water scarcity is most challenging when there is no rain but during the rainy season, especially for those that have big containers, they do collect rainwater and use it for a long time." (Interview with a married female resident in High Level: Urban, March 2017).

Drinking water access tends to become much more difficult in the dry season as a respondent from Kanshio pointed out:

> "During the rainy season, people would just harvest rainwater and drink so not many people go to the borehole to queue up. But during the dry season when there is no rain, water supply is greatly affected; there is less water supply and a lot of people go to the borehole and the queue is very long and hence more time to get the water." (Interview with a married female resident in Kanshio: Urban, March 2017).

In urban areas especially, this can create seasonal financial pressures. In the dry season many respondents in greater Makurdi purchased water with prices tending to increase with rising demand. In the rural sites where water vendors are scarce, the dry season is often characterised by long queues at boreholes and many hours spent looking for water; often from unimproved sources (see plates 2). As one female respondent noted:

> "During the rainy season our wells do have water and so we do not go far to the river looking for water. But during the dry season it is difficult because our wells are dry and there is insufficient water. We have to go far in search of water and the queueing time is long in addition to the long distance." (Interview with a married female resident in Dam: Rural, March 2017).

Another vivid picture of the situation was given by a resident from Konshisha area:

> "During the rainy season my well has water and I fetch it so we do not go far looking for water but during the dry season it is difficult to get water so we go and fetch water from the dam, and the dam water is like a place for pigs to bathe but we fetch it and drink because we don't have money. We do add alum to the water to clear and use it for cooking and drinking since we don't have another source of water." (Interview with a married female resident in Konshisha: Rural, March 2017).

The above quotes highlight how respondents' water source stacks shift from predominantly improved sources during the rainy season to a greater reliance on unimproved water sources in the dry season. In the rainy season, people have a greater choice of water sources that they can use free of cost including wells and rainwater but these choices also include unimproved sources such as ponds, rivers and dams which have abundant water during the rainy season but the quality of this water is often poor. Even when improved sources are available in the dry season, respondents often have to buy water or spend additional time collecting it (see plate 1). The regional snapshot for Africa estimates that the percentage of the population using unimproved and surface water sources was 23% and 7% in rural and urban areas respectively in 2015. In contrast, our data indicate that the use of unimproved water in urban areas is around 20% while the rural areas can be as high as 50%, especially in the dry season.

The picture of water from the Dam mentioned in the above quotation is shown in plate 2.

Plate 1: Water buying in Makurdi (a) and Borehole queues at Tse-Agberagba (b)
Source: Fieldwork 2017

An example of visibly poor water that can be seen with naked eye is shown in plate 2. Some sources may look clean but are not safe for drinking.

Plate 2: Surface water at Tse-Agberagba (a), Sample of surface water at Tse-Agberagba(b)
Source: Fieldwork 2017

Discussion

Faecal Contamination

The results show that there were higher levels of faecal water contamination in the dry season compared to the rainy season. These findings contrast with studies by Moyo (2013), Wright, Cronin et al. (2013), Kostyla, Bain et al. (2015), Cassivi, Tilley et al. (2021) which reported higher contamination in the wet season but echo those by Chidavaenzi, Jere et al. (1997), Palamuleni (2002), Kulabako, Nalubega et al. (2007), Tukur and Amadi (2014) which found higher contamination in the dry season. Godfrey, Timo et al. (2006) linked higher dry season contamination to pressure on fewer available water sources. In terms of sanitation, the dry season posed more problems in terms of getting access to water to flush toilets and wash hands (Akelo and Nzengya 2021, Cassivi, Tilley et al. 2021).

The finding of higher contamination in the urban sites tallies with the views of researchers such as Barrett, Howard et al. (2000), Howard and Bartram (2003), Nyenje, Foppen et al. (2010) Foppen and Kansiime (2009), Akelo and Nzengya (2021), Strauch, Kalumbwa et al. (2021) and Marks, Clair-Caliot et al. (2020) who noted that high urban pollution loads reflect the greater settlement density, number of people using the facilities and sometimes underlying geological conditions. As Makurdi lies in a sandy area, it is affected by high levels of contamination from sanitation facilities. For easy visualisation and comparison, the data are presented in a bar chart in figure 4. In the dry season the rural sites were more contaminated with 95% samples falling in the very high category compared to 92% of urban samples. This could be due to higher concentrations of contaminants in the dry season in rural sites linked to onsite sanitation (Kiptum and Ndambuki 2012). Godfrey, Timo et al. (2006) also reported that contamination from wells could be high in the dry season due to high usage rates and the tendency for water to become contaminated in the withdrawal process. Both the urban and rural areas had problems with sanitation in the dry season due to scarcity of water for toilet flushing and handwashing. Consequently, many people were forced to practice open defecation and go without washing their hands after toileting (Wispriyono, Arsyina et al. 2021). Omotayo, Olagunju et al. (2021) reported that households with improved WASH had less cases of diarrhoea especially in children under the age of five. In light of this, Pugel, Javernick-Will et al. (2021) advocated for collaborative pathways to improve WASH services.

Nitrates

Seasonally, the rainy season was more contaminated with nitrate than the dry season. This tallies with reports by Barrett, Howard et al. (2000), Sorensen, Lapworth et al. (2015) and Cassivi, Tilley et al. (2021) which show that higher contamination occurs after rainfall events. This is believed to be accelerated by rapid recharge of shallow groundwater which reflects in shallow well contamination. Graham and Polizzotto (2013) reported that nitrate in the rainy season is generally more contaminated than the dry season, confirming findings obtained in the field. Similarly, higher nitrate concentrations were reported in the rainy season in studies carried out in Uganda and the Democratic Republic of Congo by Kulabako, Nalubega et al. (2007), Vala, Tichagwa et al. (2011). However, in the study carried out by Taigbenu and

Mangore (2004) in Zimbabwe, lower values of nitrate were reported which could be due to the effect of dilution.

Apart from latrines being a substantial source of nitrate in well water, Kassenga and Mbuligwe (2009) found that waste dumps contribute to nitrate loading in well water. The sites with high nitrate values correspond with the most polluted sites. The nitrate contamination therefore showed a significant variation among the sites and between the seasons.
Nitrate had higher values in the urban than the rural areas in the rainy season. This tallies with Isunju, Schwartz et al. (2011), Ademas, Adane et al. (2021)'s view that urban areas have higher nitrogen loading from on-site sanitation systems than their rural counterparts. Threats from nitrate from on-site sanitation have been reported by many researchers (Tandia, Diop et al. 1999, Zingoni, Love et al. 2005, Kimani-Murage and Ngindu 2007, Vinger, Hlophe et al. 2012, Wright, Cronin et al. 2013). Nitrates were also found to be higher in the rainy than the dry season. This tallies with findings reported by other researchers of higher nitrate concentration in the rainy than dry season (Kulabako, Nalubega et al. 2007, Vala, Tichagwa et al. 2011, Dotro, Langergraber et al. 2017, Ademas, Adane et al. 2021).

Chloride

Chloride values were found to be higher in the urban than the rural areas in the study. Many researchers also reported higher groundwater contamination by chloride in the urban areas due to latrine density (Verheyen, Timmen-Wego et al. 2009, Wright, Cronin et al. 2013, Martínez-Santos, Cerván et al. 2017). Chloride values were also found to be higher in the dry season. Howard, Bartram et al. (2003), Sorensen, Lapworth et al. (2015), Sorensen, Lapworth et al. (2015) reported higher chloride contamination after rainfall periods in Uganda and Zambia, suggesting changes in water quality in response to the recharge of shallow groundwater. On the other hand, Kulabako, Nalubega et al. (2007) study in Uganda and Palamuleni (2002) in

Malawi reported higher concentration in the dry season compared to the rainy season. These could be explained by the pulse in contaminants at the commencement of the rainy season. Echoing research carried out elsewhere (Lapworth *et al.*, 2017; Dongzagla *et al.*, 2020), both improved and unimproved wells contaminated irrespective of the seasons.

When asked about their perceptions of water quality, respondents in the study sites reported that water availability and quality created more of a challenge in the dry season as they had more limited choices than in the rainy season. In addition to the larger number of options available in the rainy season, respondents indicated that they could drink water of better quality echoing findings by other researchers including (Anorue and Modebei , Jewitt, Mahanta et al. 2018, Nguyen, Operario et al. 2021). However, it is worth noting that although in the rainy season, people have a greater choice of water sources that they can use free of cost including wells and rainwater but these choices also include unimproved sources such as ponds, rivers and dams which have abundant water during the rainy season but the quality of this water is often poor (Elliott, MacDonald et al. 2017, Pearson, Rzotkiewicz et al. 2017, Kelly, Shields et al. 2018).

Conclusion

In conclusion, access to water and sanitation varied significantly between dry and rainy seasons. Water quality also varied seasonally with the dry season being characterised by higher faecal contamination levels than the rainy season. The monitoring of water and sanitation has been carried out in the study area for many years with DHS data being collected in both seasons and access and quality varies as also found out in the research. Many people who used improved water sources in the rainy season had to switch to unimproved ones in the dry season illustrating seasonal systems of water source 'stacking' that are rarely captured in JMP data collection and SDG6 progress reporting. Although people have a greater choice of water sources in the rainy season such as wells and rainwater, these choices also include unimproved sources such as ponds, rivers and dams which have abundant but often poor-quality water during the rainy season. Faecal coliforms, nitrates, and chlorides all showed concentrations above WHO standards and confirm local perceptions of seasonally poorer water quality as indicated by the semi-structured interviews. The contaminants appear to come mainly from pit latrines. As seasonality has a substantial influence on both drinking water access and quality, we argue that this needs to be factored into future watsan data collection and monitoring.

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