Assessment of effectiveness of water safety plans (WSP) on water quality in rural communities of Anambra State, south-eastern Nigeria

Azubuike S. Ekwere, Oyonga A. Oyonga and Maingaila M. Banda

ABSTRACT

World Health Organization recommends the use of water safety plans as a systematic approach to ensure safe drinking water supply through a comprehensive risk assessment and management. This research assesses the implementation of WSPs in Anambra State, Nigeria, based on understanding the outcomes of the community's WSP implementation and provides recommendations to improve the WSP process. To meet these objectives, a mixed-methods protocol was used, including household surveys on water management practices, water quality testing to determine water safety of households' transport, stored and source waters and qualitative data collection. In an evaluation on the implementation of WSPs in two councils' areas, relative to non-WSP implementing communities, the following activities were conducted: 120 household surveys; water sample testing at water sources; focus group discussions with key informants, water facility staff. Results indicate: water sources in both councils are producing relatively clean water; water management practices at the source were relatively safe with minor risky practices in a few communities; households involved in risky practices that led to contamination from transported through to stored water and water facility caretakers were aware of their responsibilities. Recontamination of the source water during transportation and storage remained the main difficulty in ensuring consumption of safe water.

Key words | Anambra, *E. coli*, Nigeria, water, water safety plan

Azubuike S. Ekwere (corresponding author)
Oyonga A. Oyonga
Department of Geology,
University of Calabar,
Calabar,
Nigeria
E-mail: *zerratta77@yahoo.com*;
azubuike.ekwere@unical.edu.ng

Oyonga A. Oyonga
Maingaila M. Banda
UNICEF Nigeria Office,
Abuja,
Nigeria

HIGHLIGHTS

- The research assesses the application and effectiveness of water safety plans (WSPs) as a means of improving water quality in rural communities in Anambra State in Nigeria.
- The methodology of the research focuses on contaminant tracking along the water chain; from source to consumer.
- Results and analysis of data indicates an effective influence of the WSP. Also indications are that water supply, hygiene and sanitation affects water quality within the study area.

INTRODUCTION

Water is one of the most important natural resources for the survival of man and its unavailability or deterioration in quality poses a serious environmental and health challenge to most communities in the world. The need to provide safely managed drinking water for all has remained a paramount component of the Millennium Development Goals (MDGs), and currently the Sustainable Development Goals (SDGs) UN-DSDG (2018). A safely managed drinking

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water source is defined as an improved source located on premises, available when needed, and free from microbiological and priority chemical contamination (WHO 2017a).

Provision of safely managed drinking water sources, involves a series of systematic approaches and these have been designed and recommended by the World Health Organization as water safety plans (WSPs) (WHO 2017b). The goal of a WSP is to manage water supply such that health-based targets are met (Davison *et al.* 2006). WSPs also attempt to achieve the safety of drinking-water supply by implementing a vulnerability and risk assessment as well as risk management along the water supply chain from source to consumer. These recommended approaches have been implemented in communities worldwide, but indications are that there are no standardized effectiveness assessments, but rather these are subjective with local considerations of implementation communities. Some of the countries with case studies where WSPs have been effectively implemented include Cambodia, Lebanon, Ghana, Liberia, Tajikistan, Madagascar and Uganda (WHO & UNICEF 2019).

The absence of indicator organisms in drinking water does not provide sufficient guarantee for microbial safety (Smeets *et al.* 2010). This necessitates the need for qualitative and semi-quantitative risk assessment in application of WSPs (Davison *et al.* 2006). These qualitative and quantitative approaches have been applied in WSP implementation and assessment modules in different sites worldwide with varying prevalent conditions. Examples of such abound in research literatures, including Haas *et al.* (1999), Davison *et al.* (2005), Medema *et al.* (2006), Mahmud *et al.* (2007), Smeets *et al.* (2008), Teunis *et al.* (2009) and Smeets *et al.* (2010).

Although the Centres for Disease Control and Prevention developed a method for evaluation across four key outcomes areas, evidence in support of the WSP methodology is lacking in published literature, particularly for rural, community-managed implementations (String & Lantagne 2016).

In Nigeria, WSPs are mandated in the Nigerian Standard for Drinking Water Quality, which was adopted in 2007. WSPs are required for all water service providers, including community-managed water committees.

The country-based WSP mandate is geared towards putting in place a preventive management framework for safe drinking water where risks to drinking water sources are identified, prioritized, and managed to prevent drinking water quality problems before they occur (FMWR & FMH 2015). The objective by extension includes support to communities to have safe drinking water through good water supply practice and management. The WSP framework also included identifying and clarifying the roles and responsibilities of stakeholders who play an important role in the provision of safe drinking-water at state, local council and community levels.

This research provides an assessment of operation and effectiveness of implementation of the WSPs, within the selected state, with the principal objective to understand the outcomes based on water management practices, water quality, and qualitative processes.

Study area

The selected study location was Anambra state in southeastern Nigeria (Figure 1), with a spread of 30 communities across the state within two local government councils (Anambra-East and Aguata) for sample collection and analyses. The choices of the selected locations were governed by the following criteria:

(1) Similar water source or access
(2) Similar water bearing horizons or aquifer types and
(3) Similar geomorphological and geological features.

Aguata has a total landmass area of 195 km² while Anambra East has a landmass area of 251 km². The population of Aguata is 369,972 while Anambra East is 152,149 (2006 census).

The geology of the study area defined as the Anambra basin is an undulating terrain belonging to the Lower Benue Trough of south-eastern Nigeria. It forms part of the outcropping units of the Cenozoic Niger Delta (Nwajide 2013). The area is structurally bordered by the Abakaliki Anticlinorium, running northeast, and the Cameroun fault Line in the southeast. Topographic elevations range between 89 m in the highlands to as low as 22 m in the low-lying areas, with variations of up to 10 m. The area is underlain by clastic sedimentary rocks of the Asu River Group and Eze-Aku Formation (Cretaceous Age). These are expressed as lithostratigraphic units of sands, sandstone ridges, heteroliths and low lying shales or claystones (Nwajide 1980). The friable sandstone units are dominantly impregnated with intercalations of silts, clays and shales.

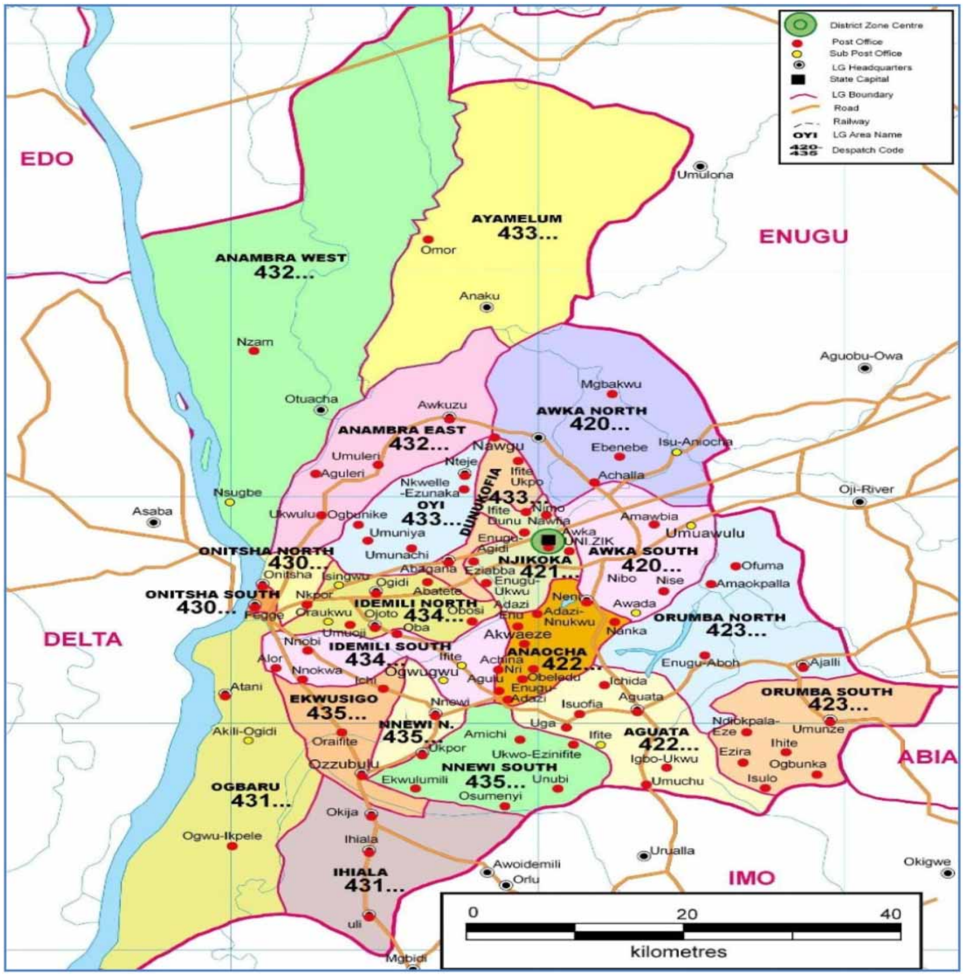

Figure 1 | Geopolitical map of Anambra State showing Aguata (422) and Anambra-East (432) (source: nigeriazipcode.com).

The area shows extensive denudation and weathering episodes evident in the development of a rich regolith profile, which supports a luxuriant agricultural land use practice. The sandstone units appear to be generally aquiferous, being fine to medium grained.

METHODOLOGY

A mixed-methods protocol was employed in this research and it included:

(1) Household surveys on water management practices;
(2) Water quality testing to determine water safety of households' transport and stored water and source waters; and
(3) Qualitative data collection, including interviews with water facility caretakers, interviews with key implementers from UNICEF and Rural Water Supply and Sanitation Agency (RUWASSA), and focus group discussions with water, sanitation, and hygiene committees (WASHCOMs).

Informed consent was collected before completing all surveys, focus group discussions, and interviews. The research was approved by Anambra State Ministry of Health, through the Nnamdi Azikiwe University Teaching Hospital Research Ethics Committee.

Household survey was based on questionnaires and observations on household demographics, knowledge, attitudes, and practices towards water, sanitation, and hygiene, as well as knowledge of Water Safety Plan work. Also measurement of water quality parameters and collection of water samples was done at households.

GPS location coordinates of sample sites were documented and water quality parameters were measured on-site. Water samples were also collected for subsequent laboratory-based water quality analysis from household transport and storage containers.

One hundred and twenty (120) households from 30 communities in two local government areas (LGAs) were visited. Sixty (60) households were from 15 communities across both LGAs where WSPs are being implemented while another 60 households were from 15 communities across both LGAs where WSPs are not implemented, to serve as control.

At the households, two water samples were collected (one from the transport container and one from the storage container). In-situ measurement of temperature, pH and total dissolved solids (TDS) was conducted at each household.

Samples for laboratory analysis were collected in sterilized 75 mL water bottles, placed in ice-packed insulator bags, and transported to a field laboratory within six hours. The samples were subjected to membrane filtration for detection of *Escherichia coli* (*E. coli*). Samples were diluted appropriately with sterile buffered water, vacuum filtered aseptically through a 45-micron filter paper, placed in a Petri dish with a media-soaked pad, and incubated for 18 hours at 35°C. Colonies were counted and concentrations calculated by averaging plate counts within a countable range (colony forming units (CFU)/plate) after accounting for dilution factors. Drinking water samples were also categorized by WHO risk guidelines for *E. coli* results as: in conformity with recommendations (<1 CFU/100 mL), low risk (1–10 CFU/100 mL), intermediate risk (11–100 CFU/10 mL), high risk (101–1,000 CFU/100 mL) and very high risk (>1,000 CFU/100 mL).

Turbidity of water samples was also measured in the field laboratory with a calibrated turbidity meter within 12 hours of sample collection. Results were recorded in nephelometric turbidity units (NTU). Source water samples were tested at the source for the same parameters and collected and processed in the field lab in the same manner. All instrumental analyses were done using the Wagtech Palintest Tool Kits.

RESULTS AND DISCUSSION

The numerical spread of the survey communities across the two local councils is as presented in Table 1. From the household surveys, mean age of respondents in Aguata was 46 years and 39 years in Anambra East, with a mean age of 42 years across both local councils (Table 2). The survey also shows a majority (89%) of the total respondents to be literate across both communities. The mean number of people in the houses across the study areas was 6.

Table 1 | Sample point type and distribution across the two LGAs

LGA	MBH with OHT	No. of WSP implementing	No. of non-WSP implementing
Aguata	15	8 (53%)	7 (47%)
Anambra East	15	7 (47%)	8 (53%)

MBH, motorised borehole; OHT, over head tank.

Observation shows eighty percent of households used jerry-cans as their transport container and this cans also serve as storage container in some households. The most frequently observed storage containers were plastic barrels and buckets, making up about 85% of storage containers.

Assessment of sanitary conditions of water transport and storage containers had 10 and 83% of respondents claiming to clean the containers daily and frequently respectively. However a random visual assessment showed the containers to have poor hygiene conditions (Figure 2).

About 63% of respondents were of the view that water could make them sick; however, only a meagre 13% of the respondents reported treating the water in their homes and the major water treatment method was boiling and use of chlorine tablets (Table 2).

Water quality testing

Assessment of WSP and non-WSP implementing communities shows that twelve (12) of the fifteen (15) communities in the WSP implementing communities across both local councils have their source waters devoid of contamination, and this represents 80%. The other 20% are of low risk values. For the non-WSP implementing communities, 10 of 15 representing approximately 67% are devoid of contamination, 4 (approximately. 27%) are of low risk value while one (1) community had its source to be of medium risk value.

In the WSP implementing communities, five households recorded storage water with *E. coli* values too numerous to

Table 2 | Survey demographic response data in each local council

Variable	Aguata $n = 60$	Anambra East $n = 60$	Total $n = 120$
Mean age of the respondent (SD)	46 (19)	39 (15)	42 (17)
Respondent attended school	16 (27%)	37 (62%)	53 (44%)
Female head of the house can read	8 (13%)	12 (20%)	72 (60%)
Male head of the house can read	17 (28%)	40 (67%)	77 (64%)
Mean people in the house (SD)	6 (3)	7 (4)	6 (3)
At least one member in the house had diarrhea last week	0 (0%)	4 (7%)	4 (3%)
Volume of water transport container (Liters)	22	22	22
Volume of storage container (Liters)	80	78	80
Cleans the container: daily	2 (3%)	10 (16%)	12 (10%)
Cleans the container: frequently	52 (87%)	47 (78%)	99 (83%)
Thinks water can make them sick	24 (40%)	52 (87%)	76 (63%)
Treats the water in the house	9 (15%)	7 (11%)	16 (13%)
Treatment method:	$n = 9$	$n = 7$	$n = 16$
Cloth filter	–	–	–
Boiling	7 (78%)	3 (43%)	10 (8%)
Chlorine tablet	2 (22%)	3 (43%)	5 (4%)
Other types of filter	–	–	–

Figure 2 | (1) Damaged and unhygienic transport container as seen at a source in Aguata; (2) Inside view of an empty transport container in Anambra-East; (3) Water storage at a household in Anambra-East.

count (TNTC) while in the non-WSP communities, six transported waters and eight storage waters indicated TNTC for *E. Coli*.

Assessment of geometric mean values of *E. coli* relative to WHO risk standard for transported and stored water indicated only one community (Umuezealor Okpoko Isuofia) in the WSP implementing communities to be within conformity; that is, devoid of any contamination along the water chain. The community visibly exhibits excellent sanitary and hygienic awareness levels evident from sanitary conditions of the water source facilities as well as frequent awareness campaigns by the local WASHCOM and adherence to same by the local populace.

Three (3) communities (20%) were of low risk, nine (60%) of medium risk, one (1) each of high and very high risk values.

In the non-WSP implementing communities, no community was devoid of contamination in transported and

Table 3 | Geometric mean of *E. coli* and turbidity

Parameter	Transport Aguata (*n* = 60)	Transport Anambra East (*n* = 60)	Storage Aguata (*n* = 60)	Storage Anambra East (*n* = 60)
Geometric mean of *E. coli*/100 mL	32.9	15.5	41.5	70.2
Geometric mean turbidity (NTU)	0.41	1.41	0.56	1.26

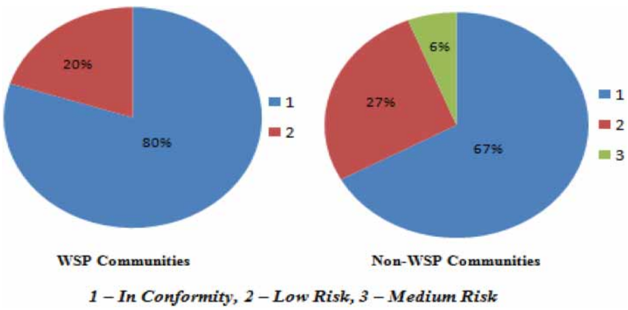

Figure 3 | WHO assessment of source water from WSP and non-WSP implementing communities.

stored waters. Four (4) communities (approximately 27%) were of low risk, seven (approximately 47%) of medium risk, 1 of high risk and 3 (20%) of very high risk.

Geometric mean water quality parameters were calculated for all household water samples ($n = 120$) (Table 3). In source water, geometric mean *E. coli* concentration was 0.54 CFU/100 mL and turbidity was 0.92 NTU. In transport and storage containers, geometric mean *E. coli* concentrations were 24.3 CFU/100 mL and 55.9 CFU/100 mL and turbidity was 0.91 NTU and 0.91 NTU, respectively. General observation indicates geometric mean of *E. coli* concentration and turbidity increased from source through storage, indicating water quality deterioration along the water chain (Figure 3). *E. coli* concentrations were statistically significantly higher in transported samples from Aguata than those of Anambra East, while for storage, concentrations were higher for Anambra East than in Aguata. Three (3) source samples in Aguata recorded *E. coli* contamination while seven (7) recorded same in Anambra East.

Statistical distribution trends of *E. coli* and turbidity in source, transport and storage samples for the two study areas are presented in Figure 4.

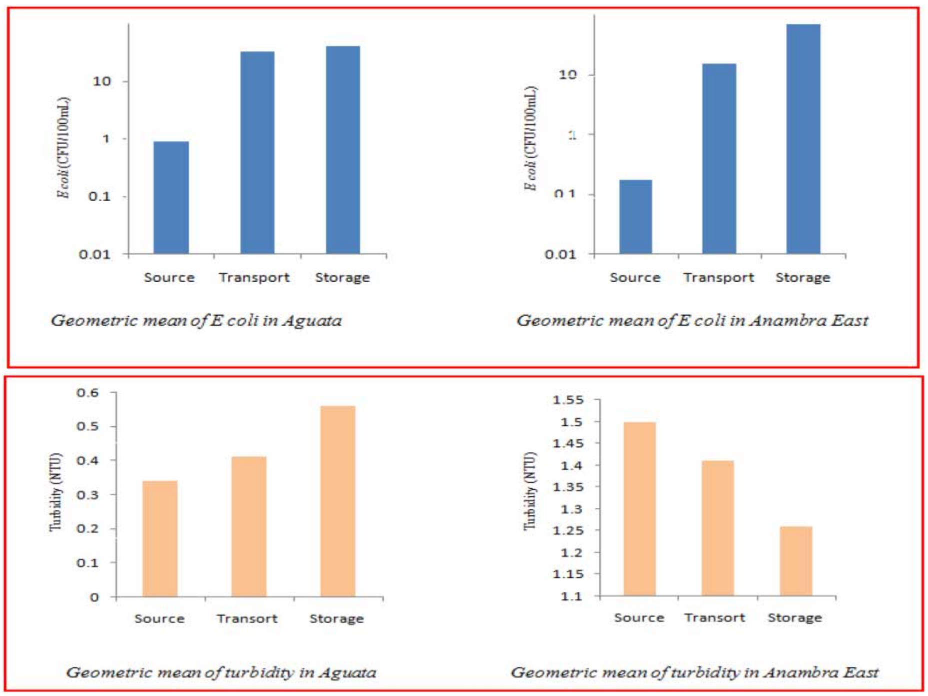

Figure 4 | Geometric mean of *E. coli* and turbidity in source, transport and storage samples.

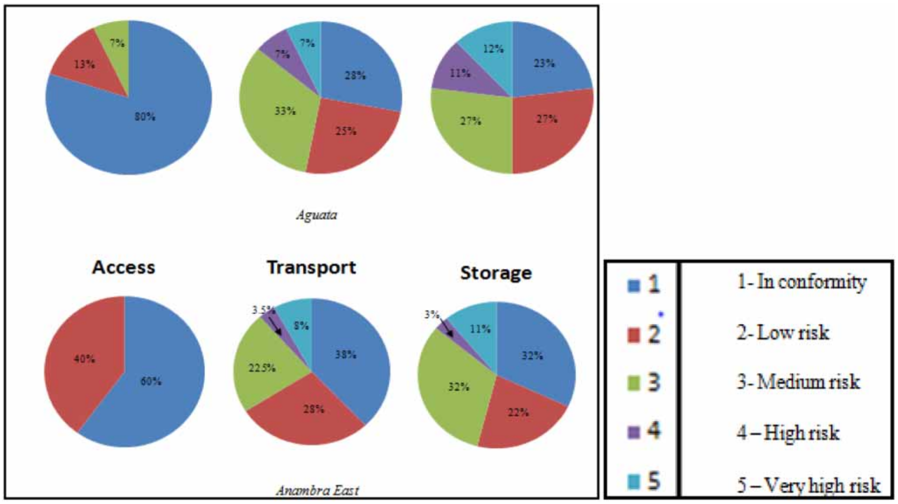

Figure 5 | Percentage of source, transport, and storage samples according to WHO risk category.

In Aguata 4 transport and 7 storage samples had too numerous to count (TNTC) values for *E. coli,* while in Anambra East TNTC values were reported for 5 transport and 7 storage samples. The samples with TNTC values indicate very high risk based on the WHO drinking water standards.

Assessment indicates (Figure 5) eighty percent (80%) of the source samples in Aguata to be within conformity of the standard, 13% with low risk and 7% with medium risk. In Anambra East, the source samples had 60% in conformity and the remaining 40% to be of low risk. For the transport and stored water samples, the trends of variation were similar, but Anambra East had a higher percentage of samples within conformity of potable water as defined by the WHO standard. General assessment indicates that transport and storage container samples from Anambra East communities were prone to more recontamination, as compared to Aguata communities.

The noticeably increased contamination from source to storage can be adjudged to poor water management and hygiene practices, and this is a common trend in both WSP and non-WSP communities across both LGAs. Unhealthy practices such as the use of communal funnels, usually prone to contamination, to collect water and unhygienic containers for transport and storage are major sources of contamination. The high percentage of claims to cleaning transport and storage containers from the household surveys appears at variance to the contamination indices.

CONCLUSIONS

Evaluation on implementation of water safety plans and its effectiveness in two local councils of Anambra were conducted. The following observations were made from the assessment:

(1) Water sources in the WSP and non-WSP implementing communities in both local councils are producing clean water.
(2) Water management practices at some of the sources leads to contamination of the source water and this was more prevalent in the non-WSP implementing communities.
(3) Water management practices in households involved risky practices that can contribute to the recontamination of the water, from transportation through to storage, both in WSP and non-WSP communities.

Concentration of *E. coli* along the water chain showed 'conformity' according to the WHO standard of <1 CFU/100 mL in only one WSP community. Other communities exhibit low risk values at source but recontamination increases from transport to storage.

The WSP program has however improved water management from source to storage in WSP-implementing communities.

Contamination of the source water during transportation and storage remains a main problem in ensuring consumption of safe water.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

REFERENCES

Davison, A., Howard, G., Stevens, M., Callon, P., Fewtrell, L., Deere, D. & Bartham, J. 2005 *Water Safety Plans: Managing Drinking-Water Quality From Catchment to Consumer*. Water, Sanitation and Health Protection and the Human Enviroment, World Health Organization, Geneva, Switzerland.

Davison, A., Deere, D., Stevens, M., Howard, G. & Bartham, J. 2006 *Water Safety Plan Manual*. WHO, Geneva, Switzerland. Available from: http://www.who.int

Federal Ministry of Water Resources & Federal Ministry of Health (FMWR & FMH) 2015 *Community Led Water Safety Planning: A Step-by-Step Approach to the Formulation of Community Led Water Safety Plan for Simple Rural Water Supply Schemes in Nigeria*.

Haas, C. N., Rose, J. B. & Gerba, C. P. 1999 *Quantitative Microbial Risk Assessment*. Wiley, New York, NY, USA.

Mahmud, S. G., Shamsuddin, S. K., Ahmed, M. F., Davison, A., Deere, D. & Howard, G. 2007 Development and implementation of water safety plans for small water schemes in Bangladesh: benefits and lessons learned. *Journal of Water and Health* **5** (4), 587–597.

Medema, G. J., Loret, J. F., Stentröm, T. A. & Ashbolt, N. (eds) 2006 *Quantitative Microbial Risk Assessment in the Water Safety Plan, Report for the European Commission Under the Fifth Framework Programme*. Theme 4: 'Energy, environment and sustainable development', The Netherlands. Available from: http://www.microrisk.com

Nwajide, C. S. 1980 *Geology of Nigeria's Sedimentary Basins*. CSS Press, Lagos, Nigeria, pp. 381–504.

Nwajide, C. S. 2013 Eocene tidal sedimentation in the Anambra Basin, Southern Nigeria. *Sedimentary Geology* **25**, 189–207.

Smeets, P. W. M. H., Medema, G. J., Dullemont, Y. J., Van Gelder, P. & Van Dijk, J. C. 2008 Improved methods for modelling drinking water treatment in quantitative microbial risk assessment; a case study of Campylobacter reduction by filtration and ozonation. *Journal of Water and Health* **6** (3), 301–314.

Smeets, P. W. M. H., Rietveld, L. C., Dijk, V. & Medema, G. J. 2010 Practical applications of quantitative microbial risk assessment (QMRA) for water safety plans. *Water Science and Technology* **61** (6), 1561–1568.

String, G. & Lantagne, D. A. 2016 A sytematic review of outcomes and lessons learned from general, rural and country-specific Water Safety Plan implementations. *Water Science and Technology Water Supply* **16** (6), 1580–1594.

Teunis, P. F., Rutjes, S. A., Weshell, T. & de Roda Husman, A. M. 2009 Characterization of drinking water treatment for virus risk assessment. *Water Research* **43** (2), 395–404.

UN-DSDG 2018 *Sustainable Development Goal 6*. Available from: https://sustainabledevelopment.un.org/sdg6

World Health Organization & UNICEF 2019 *WASH in Healthcare Facilities: Global Baseline Report 2019*. WHO Press, Geneva, Switzerland.

World Health Organization, WHO 2017a *Safely Managed Drinking Water – Thematic Report on Drinking Water*. WHO Press, Geneva, Switzerland.

World Health Organization, WHO 2017b *Guidelines for Drinking-Water Quality*, 4th edn. World Health Organization, Geneva, Switzerland.

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