Journal of Water & Health

Journal of Water and Health Vol 21 No 8, 1051 doi: 10.2166/wh.2023.076

Exploring the nexus of water insecurity and psychological distress in Windhoek's informal settlements, Namibia

Tobias Willem Shinyemba * and Khanyisile Cloete

Department of Computing, Mathematical and Statistical Sciences, School of Science, University of Namibia, Private Bag 13301, Windhoek, Namibia
*Corresponding author. E-mail: tshinyemba@unam.na

TWS, 0000-0003-0837-937X

ABSTRACT

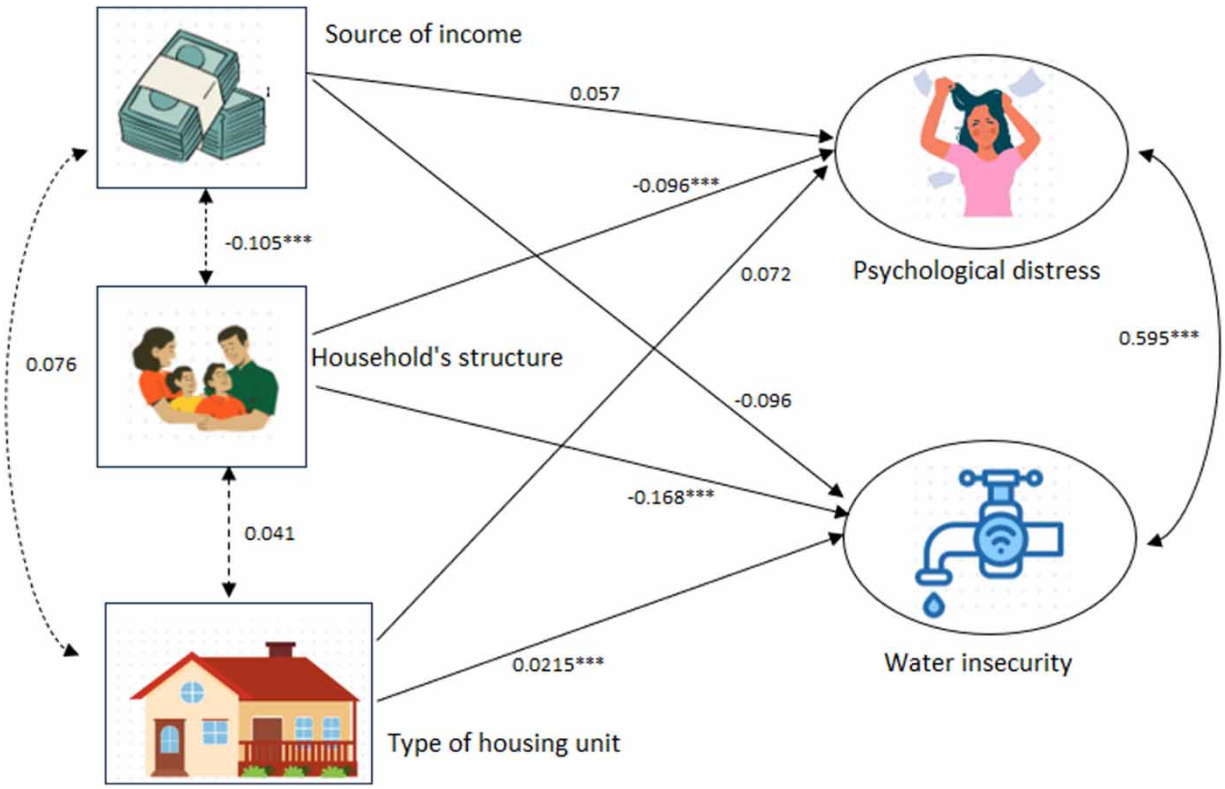
Water insecurity has long been a pressing issue, particularly in the informal settlements of Windhoek. The current study aims to investigate the relationship between water insecurity and residents' psychological distress in Windhoek's informal settlements. The study draws upon secondary data collected by Future Resilience for African Cities and Lands in 2017. Confirmatory factor analysis was used to establish the relationship between water insecurity, psychological distress, and three manifest variables (source of income, housing type, and household structure). The study findings revealed a positive association between housing type and psychological distress ($\beta = 0.056$, $p < 0.001$). Household structure was negatively associated with psychological distress ($\beta = -0.035$, $p < 0.001$) and water insecurity ($\beta = -0.054$, $p < 0.001$). In addition, a positive association ($\beta = 0.595$, $p < 0.001$) was found between water insecurity and psychological distress, suggesting that water scarcity negatively impacts residents' mental well-being. The study highlights the need to address the issue of water insecurity in informal settlements across Windhoek. This can be achieved by setting measures to make water and essential sanitation services more accessible and affordable to residents in these communities. Such approaches would help mitigate the effect of water insecurity on the psychological distress of persons living in informal settlements and create more resilient and sustainable settlements.

Key words: informal settlements, Namibia, psychological distress, water, water insecurity, Windhoek

HIGHLIGHTS

- Approximately 78.8% of the interviewed households lived in shacks.
- Fetching water from neighbours owing to water shortages in certain households accounted for around 64.2% of variation in water insecurity.
- Water insecurity was negatively related to household structure.
- There was a negative relationship between psychological distress and household structure.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Water insecurity is a critical issue that hampers healthy living, characterised by insufficient and unsafe water supply (Wutich 2020). Approximately four billion people globally experience severe water shortages for at least a month each year, while 50 million endure acute water insecurity yearly (Adams *et al.* 2020). Despite efforts to improve access to clean and adequate drinking water and sanitation in the Global South over the past two decades, more than 1.8 billion people still lack these resources, and around 663 million still lack access to safe drinking water within a 1-kilometre radius of their homes (Adams 2018; Nounkeu & Dharod 2019; Kangmennaang *et al.* 2020). The consequences of using or drinking contaminated water are detrimental to health, as waterborne diseases claim the lives of around 2,195 children daily, surpassing the combined mortality of HIV/AIDS, malaria, and measles (Paudel *et al.* 2021). Waterborne infections are the second leading cause of mortality in children under-five, responsible for one in every nine children's deaths globally (Paudel *et al.* 2021). Additionally, polluted water claims the lives of over 1.2 million people annually across all age groups, more than all other types of violence combined (Biswas & Tortajada 2019).

Water insecurity arises due to the unequal distribution of water resources, resulting in significant challenges for a large section of the world population in accessing clean drinking water. In Sub-Saharan Africa, for example, 29% of the population struggles to reach nearby clean water sources, disproportionally affecting women and girls who must walk long distances to fetch water (Nounkeu & Dharod 2019; Isaacman & Musemwa 2021). These inequalities in water access give rise to concerns regarding water governance and politics (Isaacman & Musemwa 2021). Moreover, water availability impacts general health, including physical and mental well-being, job opportunities, and access to education (Beard & Mitlin 2021; Young *et al.* 2021b).

The increasing global population and its demands have exacerbated the issue of water scarcity in developing countries. The pressure on resources in these countries, aggravated by variable rainfall patterns and rising global temperature, has led to recurring water shortages (Livingston 2021; van Rensburg & Tortajada 2021). The situation is particularly pronounced in cities in the Global South, such as Sub-Saharan Africa, South Asia, and Latin America, where access to safe

drinking water is infrequent, posing a higher risk of waterborne diseases and microbiological contamination (Beard & Mitlin 2021).

Contaminated water carries a range of diseases, including cholera, typhoid fever, diarrhoea, hepatitis E, and polio, and may contain hazardous chemicals such as pesticides, heavy metals, and industrial toxins, posing risks to human health (Haseena *et al.* 2017; Postigo *et al.* 2018; Livingston 2021). In regions affected by clean water shortages, urban residents, including those in informal settlements, often resort to sources outside their homes, such as public standing pipes, boreholes, sachet water, tanker-truck services, and water from small-scale vendors. However, these sources are often insufficient, shared among many individuals, unsafe, or unaffordable for a significant portion of the population (Adams *et al.* 2020).

In Namibia, access to water is a persistent challenge due to its classification as one of the driest countries in Sub-Saharan Africa, characterised by unpredictable rainfall and a high evaporation rate (van den Berg *et al.* 2021). The need for safe drinking water and sanitary services was recognised in 1990 when the country gained independence from South Africa. However, despite numerous interventions put in place by the Ministry of Agriculture, Water and Land Reform to improve access to quality services and sustainable water supply, water access remains a challenge, particularly in rural areas and informal settlements, due to long distances between water collection points and households, as well as the high cost of water (Lewis *et al.* 2018). As a result, some residents are compelled to use water from contaminated sources such as riverbeds and sewage, posing serious health risks (Lewis *et al.* 2018).

The rapid population growth, especially in Windhoek, the capital of Namibia, has further strained the city's resources, including land and water supply. The influx of migrants seeking better living conditions has outpaced the city's economic progress, leading to the rapid development of informal settlements (Scott *et al.* 2018). Residents in these settlements are predominantly poor with low-paying jobs and face challenges accessing potable water compared to formal residential areas (Lewis *et al.* 2018). During the rainy season, they often must walk long distances to communal water taps or rely on contaminated water sources, such as riverbeds. These sources are frequently contaminated, spreading diseases such as diarrhoea, hepatitis E, and typhoid fever (Shikongo 2020, 2022).

The relationship between water insecurity and well-being has been extensively researched. For instance, Sub-Saharan African populations face health risks because of a lack of clean water supply and adequate sanitation (Zerbo *et al.* 2020). Similarly, residents in the U.S. colonias suffer from waterborne diseases resulting from polluted water from unsafe storage (Zheng *et al.* 2022). Waterborne diseases intensify the burden of infectious and non-communicable diseases, malnutrition, and injury, particularly among children under-five. Therefore, examining the everyday health problems in urban informal settlements is essential to fully understand the risks associated with water scarcity. In addition to bacterial infections and other health-related problems, water insecurity also impacts psychological distress, causing anxiety, worry, and restlessness among individuals (Bulled 2017; Kangmennaang *et al.* 2020; Brewis *et al.* 2021). A study conducted in Ghanaian slums has emphasised the need to address the physical lack of access to water and the psychological and sociological repercussions for vulnerable populations (Kangmennaang *et al.* 2020). The findings were similar to those of Kangmennaang & Elliott (2021) subsequent study, which emphasised the need to take a holistic approach to understand water insecurity and overall well-being.

Water insecurity poses significant threats to the health and well-being of individuals living in informal settlements. The problem can worsen if left unaddressed, leading to increased diseases and potential loss of lives. In these settlements, residents often have to undertake long journeys to get water, and the sources they rely on are frequently unreliable and susceptible to contamination, making the water unfit for consumption. This situation gives rise to feelings of anxiety, worry, and despair among the population. Moreover, water insecurity contributes to various health issues, including compromised personal and household hygiene. While studies have been conducted in Ethiopia (Brewis *et al.* 2021) and South Africa (Bulled 2017) to investigate the impact of water insecurity on emotional and psychological distress in rural populations using structural equation modelling (SEM) and path analysis, there remains a dearth of research on this topic specifically in informal settlements in Namibia. Despite efforts to mitigate water insecurity in Namibia, assessing its impact on psychological distress in Windhoek's informal settlements is crucial. The study aims to indirectly link and quantify the association between water insecurity and psychological distress, considering factors such as household income, household structure, and the type of housing unit. Understanding this association can inform targeted interventions and policies to improve water access, sanitation, and overall well-being in these communities.

2. METHODS

2.1. Research design

The study followed a quantitative cross-sectional research design utilising secondary data from the 2017 Future Resilience for African Cities and Lands (FRACTAL) project conducted by the Department of Statistics and Population Studies and the Department of Biological Sciences of the University of Namibia. This project aimed to understand how households in Windhoek source their water and other social and economic issues related to water security and livelihood.

The study focused on households in informal settlements of Windhoek, specifically in the Samora Machel, Tobias Hainyeko, Moses Garöeb, and Windhoek Rural constituency (see Figure 1). A sample of 900 households was chosen using a two-stage cluster sampling method, where 35 Enumeration Areas were randomly selected across 10 constituencies in the Khomas Region. Afterwards, households were systematically chosen in the second stage within the study areas to reach the desired sample size. However, our analysis only included 697 households in informal settlements and excluded 203 from formalised suburbs.

The sample questionnaire used to collect household data is provided as Supplementary Appendix A, 'Sample Baseline Questionnaire'. The questionnaire included: 18 questions on water insecurity based on the Household Water Insecurity Experience (HWISE) Scale detailing where and how households acquire and use water; 10 questions based on the Kessler psychological distress scale (K10); and three questions on household information (household structure, housing unit, and source of income). Questions on water insecurity and psychological distress required respondents to recall events in the past 30 days before the survey. These questions were used as proxies in our analysis. For a detailed description of the survey questions and variables structures, see Supplementary Appendix A: 'Sample Baseline Questionnaire'.

2.2. Ethical clearance

The University of Namibia, Research Ethics Committee, granted ethical approval for the FRACTAL project to collect primary data in 2017, while approval to use the collected data for this study was obtained from the principal investigator (Professor Lawrence Kazembe).

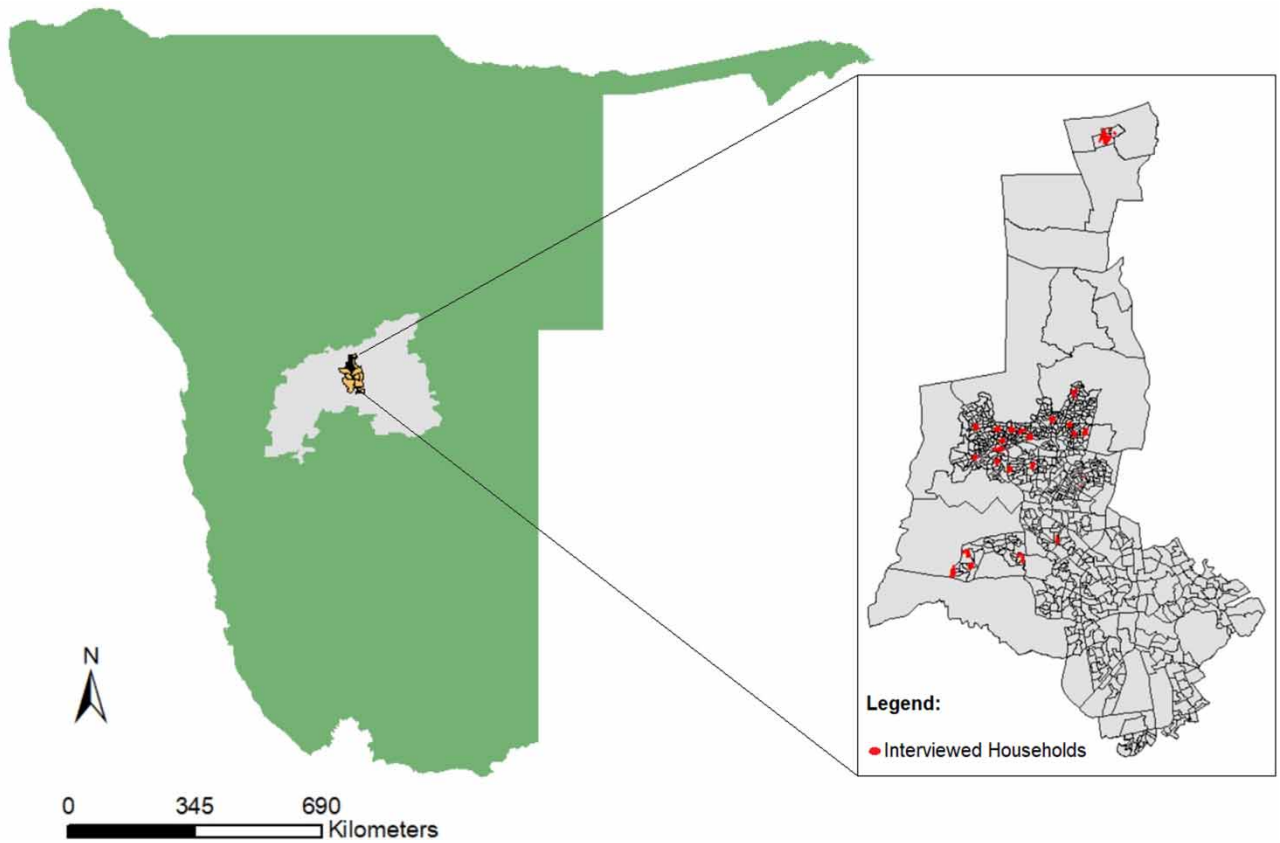


Figure 1 | Study site.

2.3. Data analysis

We analysed the data using factor analysis (FA). FA is beneficial when describing and estimating linear associations between manifest variables and latent variables or when there is a need to validate or refute a theory about a specific phenomenon. The technique is similar to the multiple regression techniques and can be split into two ways: (1) exploratory factor analysis (EFA) to explore the relationships between manifest variables and factors and (2) confirmatory factor analysis (CFA) to test a specific factor structure where manifest variables are related to specific factors (Everitt & Hothorn 2011).

To fit the FA model, we assume that there is a set of variables observed, say variables $x' = [x_1, x_2, \ldots, x_p]$, assumed to be linked to a smaller number of unobserved latent variables, $f_1, f_2, \ldots, f_p$, where $k < p$ by a regression model of the form:

$$
\begin{aligned}
x_1 &= \lambda_{11}f_1 + \lambda_{12}f_2 + \cdots + \lambda_{1k}f_k + u_1 + \varepsilon_1 \\
x_2 &= \lambda_{21}f_2 + \lambda_{22}f_2 + \cdots + \lambda_{2k}f_k + u_2 + \varepsilon_2 \\
&\vdots \\
x_p &= \lambda_{p1}f_1 + \lambda_{p2}f_2 + \cdots + \lambda_{pk}f_k + u_k + \varepsilon_p
\end{aligned}
$$

This equation can be rewritten as:

$$x = \wedge f + u \tag{1}$$

$$\text{where } \wedge = \begin{pmatrix} \lambda_{11} & \cdots & \lambda_{1k} \\ \vdots & \vdots & \vdots \\ \lambda_{p1} & \cdots & \lambda_{pk} \end{pmatrix}, f = \begin{pmatrix} f_1 \\ \vdots \\ f_k \end{pmatrix}, u = \begin{pmatrix} u_1 \\ \vdots \\ u_p \end{pmatrix}$$

We further assumed that the 'residual' terms $u_1, \ldots, u_p$ are uncorrelated with the factors $f_1, \ldots j_k$. Furthermore, we assume the factors are standardised, with a mean of zero and a standard deviation of one. With these assumptions, the factor model shown above suggests that variable variance x_i, σ_i^2, we defined it as:

$$\sigma_i^2 = \sum_{j=1}^{k} \lambda_{ij}^2 + \psi_i \tag{2}$$

where ψ_i is the variance of u_i. The FA method implies that the variance of each observed variable can be split into two parts. The first, h_i^2, which represents the variance shared with other variables via common factors, is given by:

$$h_i^2 = \sum_{j=1}^{k} \lambda_{ij}^2 \tag{3}$$

The second part, ψ_i, is called the specific variance and relates to the variability in x_i not shared with other variables. The factor model leads to the following expression for the covariance of variables x_i and x_j:

$$\sigma_{ij} = \sum_{l=1}^{k} \lambda_{il}\lambda_{jl} \tag{4}$$

CFA models are simple versions of SEM, a more generic approach for modelling latent variables. The SEM defines latent factors concerning manifest variables. Regression equations capture the moderating effects between observed and unobserved covariates, with the resulting relationship illustrated using a path diagram and a simplex model (Everitt & Hothorn 2011, p. 302). The maximum likelihood model will be used to estimate the parameters in the study factor models. The likelihood function for the k-factor model is expressed as:

$$L = -\frac{1}{2}n\{\ln|\wedge\wedge' + \psi| + \text{trace}(S|\wedge\wedge' + \psi|^{-1})\} \tag{5}$$

We minimised the function F using:

$$F = \ln|\wedge\wedge' + \psi| + \text{trace}(S|\wedge\wedge' + \psi|^{-1}) - \ln|S| - p \quad (6)$$

F takes the value zero if $\wedge\wedge' + \psi$ equals S and values greater than zero otherwise (Everitt & Hothorn 2011).

The R Core Team (2022) software (version 4.2.1) was used to analyse the data for this study, with the help of various packages such as *GPArotation*, *grideExtra*, *qgraph*, *knitr*, *dplyr*, *tidyr*, *OpenMX*, *lavaan*, *semPlot*, *semTools*, *nonnest2*, *MVN*, and *lattice*.

3. RESULTS

3.1. Households' characteristics

To investigate the relationship between water insecurity and residents' psychological distress in Windhoek's informal settlements, we begin by examining participants' (a) household structure, (b) sources of income, and (c) the type of housing unit in which they lived. These factors were essential to describe how water is shared, accessed, and financed. We analysed data from 697 households. Figure 2(a) shows that a quarter of the households were male-centred, followed by nuclear and extended family households. Knowing the living arrangements of a household allows us to understand how decisions are made within the context of a household since these decisions may influence water insecurity and psychological distress outcomes.

For source of income, nearly half of the households (48.9%) earned their income from formal wage work, followed by 15.9% that relied on informal wages. On the other hand, 1% of the households lived on government grants, while 0.3% indicated that they depended on informal loans, as displayed in Figure 2(b). Understanding the sources of income is beneficial

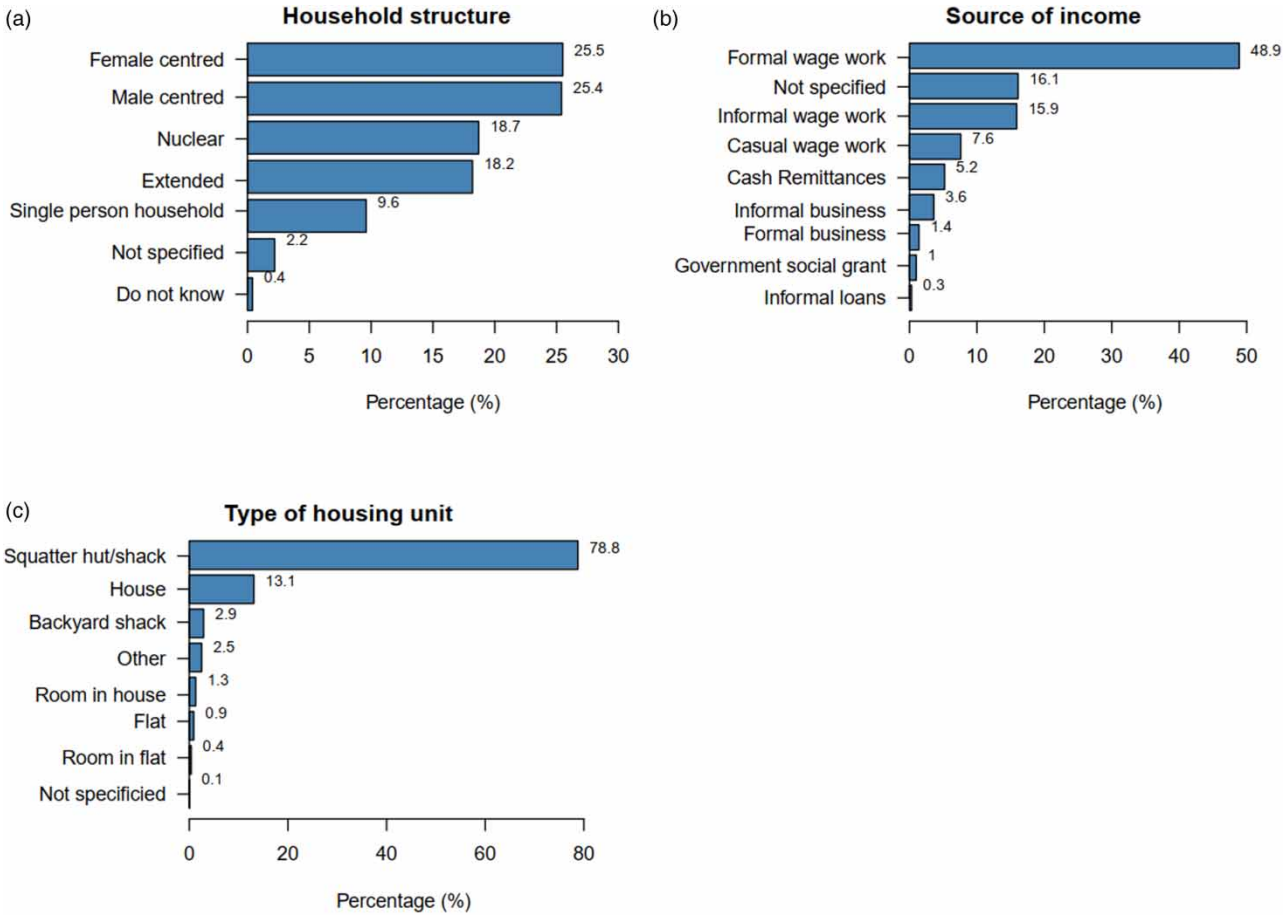


Figure 2 | Household characteristics.

because accessing safe and clean water requires money. Thus, having a guaranteed or stable income improves the households' access to water throughout the year. Furthermore, understanding the type of housing unit is significant since the chance of a household having piped running water in their compound or proximity depends on the housing unit or neighbourhood where they live. Our findings reveal that more than three-quarters of the households lived in squatter huts or shacks, and only 13.1% lived in free-standing houses, as shown in Figure 2(c).

3.2. Multivariate analysis

We used CFA to test if the hypothesised water insecurity and psychological distress constructs fit the data well. The components included questions about water insecurity and psychological distress during the FRACTAL survey. To be an optimal fit for the data, the models needed to satisfy specific statistical requirements, such as a Chi-square value ≥ 200, Root Mean Squared Error of Approximation (RMSEA) of 0.06 or less, Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) of 0.9 or higher, and an Standardised Root Mean Square Residual (SRMR) of 0.08 or less. If a model fits these criteria, we consider it a good fit, and the estimates are then assessed. We used Z-values equal to or greater than 1.96 and p-value less than 0.05 to determine the significance of manifest variables in the models.

Missing data were not imputed for the current study since the percentage of missingness ranged between 4 and 11%. Thus, we assumed that data were missing at random. As a result, households with the most significant proportion of missing data on key variables were automatically eliminated from the fitted models, as demonstrated by varying sample sizes used in three models in the current study.

3.2.1. Validating the water insecurity model

The water insecurity construct exhibited a significant Chi-square ($\chi^2_{77} = 1, 164.13, p < 0.001$) and an SRMR (0.063) within the required range, but the RMSEA = 0.145 (90% CI: 0.138; 152), CFI (0.781), and TLI (0.741) values did not, suggesting a poor model fit. However, high CFI and TLI values arise when the data is strongly correlated. Therefore, the resultant low values indicate that our data was not highly correlated, rendering the model a good fit. Table 1 shows that manifest variables included in the water insecurity construct were significant predictors, with $p < 0.001$ and Z-values greater than 1.96.

Table 1 shows positive correlations between water insecurity and its contributing factors, with factor loadings ranging from 0.426 to 0.801. The item 'Did you or anyone else in your household, because of a lack of water at home, take water from a neighbour' (Q95) ($\beta = 0.801$) and 'Did anyone who is not a member of your family take water from your house because of

Table 1 | Estimates of water insecurity ($n = 671$)

Latent variables	Estimates	Std. error	Z-value	$P(>\|Z\|)$	Factor loadings	R^2
ws =~						
Q86	1				0.685	0.469
Q87	5.541	0.342	16.216	< 0.001***	0.675	0.456
Q89	0.459	0.034	13.397	< 0.001***	0.551	0.304
Q92	0.516	0.039	13.095	< 0.001***	0.538	0.290
Q93	2.245	0.137	16.386	< 0.001***	0.683	0.466
Q94	0.285	0.027	10.446	< 0.001***	0.426	0.181
Q95	1.232	0.065	18.962	< 0.001***	0.801	0.642
Q96	1.181	0.064	18.357	< 0.001***	0.773	0.597
Q97	0.689	0.039	17.61	< 0.001***	0.738	0.545
Q100	0.537	0.031	17.103	< 0.001***	0.715	0.511
Q101	0.419	0.025	16.542	< 0.001***	0.690	0.476
Q103	0.467	0.032	14.681	< 0.001***	0.607	0.368
Q104	1.015	0.058	17.491	< 0.001***	0.733	0.537
Q105	0.405	0.034	12.061	< 0.001***	0.494	0.244

Note: ws, water insecurity; Std. error, standard error; ***$p < 0.05$.

shortage' (Q96) ($\beta = 0.773$) had the most influence on water insecurity, whereas 'Did you or any member of your household collect water from an undesirable or dirty source because you could not collect from your preferred source' (Q94) ($\beta = 0.426$) and 'Did you worry about water because of household visitors or household size' (Q105) ($\beta = 0.494$) had a minor contribution. This means that 64.2% of water insecurity is attributed to residents in informal settlements obtaining water from neighbouring households owing to a shortage of water in their own households' (Q95), whereas 59.7% is attributed to neighbours and other non-household members collecting water from different households due to lack of water in their households (Q96). In comparison, only an 18.1% variation is related to fetching water from undesirable sources (Q94). Concerns about household size or visitors (Q105) accounted for a 24.4% variation in water insecurity among informal settlers.

3.2.2. Validating psychological distress construct

We found that the psychological distress construct model fit had TLI (0.984) and CFI (0.841) values close to the cut-off point of 0.9, suggesting a satisfactory model fit. Similarly, the Chi-square ($\chi^2_{14} = 294.28$, $p < 0.001$) was significant and greater than 200, and the SRMR (0.054) was less than 0.08, indicating a good agreement. Table 2 further summarises the psychological distress model parameters. All factors significantly impact psychological distress, as indicated by Z-values ≥ 1.96 and $p < 0.001$.

Similarly, Table 2 shows positive standardised factor loadings, with significant contributions ranging from 0.676 to 0.789. Even though all variables had a substantial influence (all above 0.4), the item 'about how often did you feel so nervous that nothing could calm you down' (Q121c) was the most significant contributing factor ($\beta = 0.789$). People in informal settlements who reported that they frequently experienced nervousness and that nothing could calm them down explained 62.2% of the variation in psychological distress (Q121c). Regular restlessness experienced by informal residents explained 61.4% of the variation in psychological distress (Q121f). The lowest contributing variables were 'about how often did you feel depressed' (Q121g) and 'about how often did you feel so sad that nothing could cheer you up' (Q121i), suggesting that people who reported themselves as frequently feeling depressed explained 45.7% of the difference in psychological distress (Q121g). Furthermore, those who stated that they regularly felt unhappy and that nothing could cheer them up explained 46.5% of the difference in psychological distress (Q121i).

3.2.3. Linking water insecurity to psychological distress and household characteristics

Our model linking water insecurity and psychological distress constructs to households' characteristics produced the following fit metrics: TLI (0.783) and CFI (0.806) values, which are close to the ideal range, indicating a good fit for the model. In addition, the Chi-square ($\chi^2_{245} = 1,703.60$, $p < 0.001$) was well above the required threshold of 200, while the SRMR (0.058) value was substantially below the required threshold of 0.08, further confirming a good fit. Table 3 confirms that the water security and psychological distress model with housing type, household structure, and income was a good fit, with most Z-values significant at $p < 0.001$ and $p < 0.05$. However, the structural relation between psychological distress and housing type and source of income, and water insecurity and source of income were insignificant (see Table 3). Eliminating them from the study model did not enhance model prediction (resulting in high Akaike Information Criterion (AIC) and Expected

Table 2 | Estimates of psychological distress ($n = 695$)

Latent variables	Estimates	Std. error	Z-value	$P(>\|Z\|)$	Factor loadings	R^2
Psychological distress = ~						
Q121b	1				0.760	0.578
Q121c	0.865	0.041	21.096	<0.001***	0.789	0.622
Q121d	1.045	0.053	19.679	<0.001***	0.741	0.549
Q121e	1.008	0.049	20.516	<0.001***	0.769	0.591
Q121f	0.820	0.039	20.944	<0.001***	0.783	0.614
Q121g	1.030	0.058	17.794	<0.001***	0.676	0.457
Q121i	0.959	0.053	17.953	<0.001***	0.682	0.465

Note: Std. error, standard error; ***$p < 0.05$.

Table 3 | Estimates of water insecurity and psychological distress with housing type, household structure, and income ($n = 622$)

Latent variables	Estimates	Std. error	*Z*-value	*P*(>|*Z*|)	Factor loadings	R^2
Water insecurity						
Q86	1				0.686	0.470
Q87	5.64	0.358	15.758	<0.001***	0.679	0.461
Q89	0.47	0.036	13.009	<0.001***	0.554	0.307
Q92	0.494	0.041	12.199	<0.001***	0.518	0.269
Q93	2.259	0.141	15.973	<0.001***	0.689	0.475
Q94	0.277	0.028	10.003	<0.001***	0.422	0.178
Q95	1.235	0.067	18.360	<0.001***	0.802	0.644
Q96	1.175	0.066	17.684	<0.001***	0.770	0.592
Q97	0.68	0.04	16.816	<0.001***	0.728	0.531
Q100	0.535	0.033	16.455	<0.001***	0.712	0.506
Q101	0.436	0.027	16.37	<0.001***	0.708	0.501
Q103	0.459	0.033	13.868	<0.001***	0.593	0.352
Q104	1.01	0.06	16.792	<0.001***	0.727	0.529
Q105	0.405	0.035	11.56	<0.001***	0.490	0.240
Psychological distress						
Q121b	1				0.783	0.612
Q121c	0.871	0.04	21.541	<0.001***	0.808	0.653
Q121d	0.984	0.05	19.645	<0.001***	0.749	0.561
Q121e	0.941	0.047	20.067	<0.001***	0.762	0.581
Q121f	0.819	0.039	21.056	<0.001***	0.793	0.629
Q121g	0.966	0.056	17.108	<0.001***	0.666	0.444
Q121i	0.928	0.052	17.895	<0.001***	0.692	0.479
Regression						
wb ~ Housing type	0.021	0.012	1.719	0.086	0.072	0.005
ws ~ Housing type	0.056	0.011	5.196	<0.001***	0.215	0.046
wb ~ Household structure	−0.035	0.015	−2.284	0.022***	−0.168	0.028
ws ~ Household structure	−0.054	0.013	−4.081	<0.001***	0.215	0.046
wb ~ Income	0.012	0.009	1.349	0.177	0.057	0.003
ws ~ Income	0.005	0.007	0.650	0.515	0.026	0.001

Note: wb, psychological distress; ws, water insecurity; Std. error, standard error; ***$p < 0.05$.

Cross-Validation Index (ECVI) value). Thus, we retained the unmodified model. Therefore, the results of model modification are not presented in this paper.

The structural relationship results show that housing type positively affects water security ($\beta = 0.056$). In contrast, the household structure negatively influences psychological distress ($\beta = -0.035$) and water insecurity ($\beta = -0.054$). This implies that a unit increase in housing type (i.e., improvement in the type of housing, say from a shack to a brick house) improves water security by 0.056 units. While a unit shift in household living arrangements (say, from a single household to an extended or nuclear family) diminishes psychological distress and water security by 0.035 and 0.054 units, respectively, as shown in Table 3.

Regarding the variability contribution of household characteristics to water insecurity and psychological distress, Figure 3 shows that a 4.62% variation in distress is explained by housing type. At the same time, household structure explained a 2.82% variation in psychological distress and a 4.62% variation in water insecurity. Furthermore, the structural model shows a positive factor loading of $\beta = 0.595$ between water insecurity and psychological distress, suggesting a 35.4% variation in psychological distress is attributed to water security.

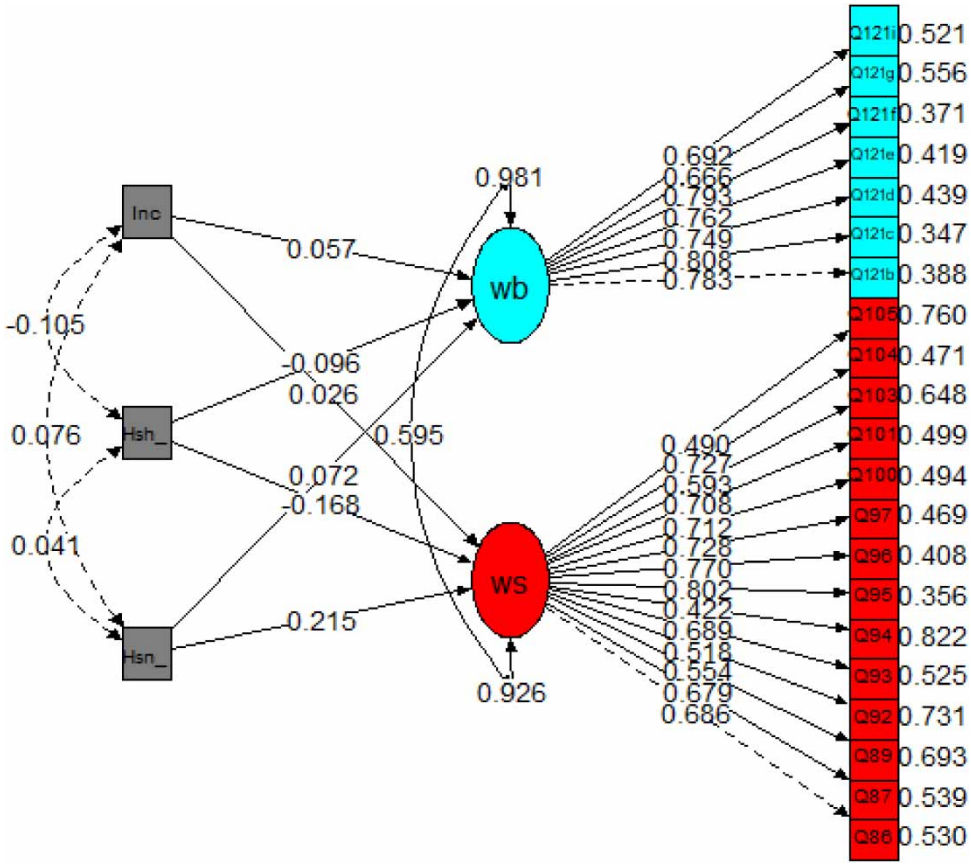


Figure 3 | Diagram linking water security and psychological distress to housing type, household structure and income. *Note*: Inc (income), Hsh (household structure), Hsn (housing type); middle: factor loadings, end of nodes: error terms.

4. DISCUSSION

The study aimed to quantify the relationship between water insecurity and residents' psychological distress with selected household attributes. We found that all manifest variables included in the constructs were significant predictors of water insecurity and psychological distress in a two-factor model of the current study.

The study found a positive association between housing type, housing structure, water insecurity, and psychological distress. However, the relationship between distress and housing type was insignificant, implying that the type of housing unit had no significant influence on residents of informal settlements' psychological distress. Nonetheless, housing type was a significant predictor of water insecurity, meaning when housing type improves, such as shifting or upgrading from a shack to a brick house, issues relating to water insecurity also improve. Our findings were similar to those of a study done in 50 metro cities in the US by Meehan *et al.* (2020), who found the lack of piped water in households to be related to the type of housing (mobile homes, rented homes, and low-income earners) where individuals lived. Comparably, Zerbo *et al.* (2020) showed that housing type was linked to health risks arising from the water supply in the households in the informal settlements.

Although we found a positive association between sources of income, water insecurity, and psychological distress, the findings were insignificant. Nevertheless, our results concur with those of Mao *et al.* (2022), who discovered no association between water insecurity, inequality, and income in 22 low- and middle-income countries. On the other hand, Mason (2014) found income to be a significant predictor of water accessibility in the Philippines, implying that as income increased, households' water access also improved. Similarly, Brewis *et al.* (2021) deduced that increased household income improved households' psychological distress and water insecurity in Ethiopia.

The study found a negative correlation between household structure, water insecurity, and psychological distress. As the number of people living in a household increase, for example, from a single-person household to an extended family, the

availability and reliability of water decrease as additional household members will require more water. This may negatively impact their mental well-being, as they may experience stress and uncertainty about water supply for personal and household use. Our findings concur with those of Motho *et al.* (2022) in Botswana, who narrated that larger households required more water for daily activities such as cooking, bathing, and laundry than smaller households. Similarly, Brewis *et al.* (2021) found a positive link between water insecurity and psychological distress.

The study also revealed a positive correlation between water insecurity and psychological distress, suggesting that water insecurity significantly impacts mental well-being. This aligns with the findings of previous research, such as Kangmennaang & Elliott (2021) and Kangmennaang *et al.* (2020), who found a strong association between water insecurity and mental distress. Factors related to water insecurity, such as lack of access to safe and adequate water for household use and consumption of water from undesirable sources, can lead to negative emotions among residents in informal settlements, such as nervousness, hopelessness, restlessness, depression, and sadness. This is consistent with the findings of Young *et al.* (2021a), who pointed out that water security played a crucial role in determining nutritional, mental, physical, and economic outcomes. This is also similar to the conclusion of Bulled (2017), who stated that people often express feelings of worry, fear, annoyance, and embarrassment about their water situations.

Moreover, this study contributes to a better understanding of water insecurity and its direct or indirect influence on population health and well-being in Windhoek's informal settlements. Furthermore, the study raises awareness of health risks associated with inadequate access to water and how to improve the situation. Additionally, the study contributes to monitoring and evaluating indicators serving two Sustainable Development Goals (SDGs): Goal 3: Abundant health and mental well-being and Goal 6: Drinking water and sanitation.

Despite the study's strengths, the study had some limitations. First, current findings may not reflect the relationship between water insecurity and psychological distress in Windhoek informal settlements since the data were collected in 2017. Second, the water insecurity and psychological distress measurements used in our study differed from other related studies, which mainly show the relationship between the two variables. Third, our model identification relied entirely on exploratory analysis, and model modification was not theoretically grounded. Thus, our study might have suffered some misspecification errors, which may have failed to establish an association between certain latent and manifest variables. Fourth, our study used income sources in the analysis instead of how much households earned, and this limited us to establish the link between income and water insecurity as well as psychological distress. Lastly, some conclusions drawn in the current study may not be reliable since we used self-reported psychological distress and water insecurity measures.

5. CONCLUSIONS

In conclusion, while there have been advances in addressing water insecurity in Windhoek's informal settlements, we acknowledge that more work still needs to be done to resolve the challenges effectively. Our study has identified ongoing water insecurity challenges faced by households in these communities, primarily due to limited water access and financial constraints. The study recommends that the City of Windhoek (CoW) take decisive action to enhance the living conditions in informal settlements. This should include prioritising improvements in access to water, upgrading the housing infrastructures, and organisation of the overall structure of the informal settlements. To ensure sustainable progress, the CoW and other relevant stakeholders must implement adequate measures that guarantee reliable and accessible water sources, promote proper hygiene practices, and provide essential sanitation facilities. By addressing these critical aspects, the CoW can significantly improve the well-being and overall quality of life of residents living in informal settlements.

ACKNOWLEDGEMENTS

The authors acknowledge Dr Opeoluwa Oyedele for reviewing the initial draft of this paper and Professor Lawrence Kazembe for availing the FRACTAL dataset for our analysis.

FUNDING

Data collection was funded by the FRACTAL project in 2017. No funding was required for data manuscript writing and data analysis.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Adams, E. A. 2018 Thirsty slums in African cities: Household water insecurity in urban informal settlements of Lilongwe, Malawi. *International Journal of Water Resources Development* **34** (6), 869–887. https://doi.org/10.1080/07900627.2017.1322941.

Adams, E. A., Stoler, J. & Adams, Y. 2020 Water insecurity and urban poverty in the Global South: Implications for health and human biology. *American Journal of Human Biology* **32** (1), e23368. https://doi.org/10.1002/ajhb.23368.

Beard, V. A. & Mitlin, D. 2021 Water access in global South cities: The challenges of intermittency and affordability. *World Development* **147**, 105625. https://doi.org/10.1016/j.worlddev.2021.105625.

Biswas, A. K. & Tortajada, C. 2019 Water quality management: A globally neglected issue. *International Journal of Water Resources Development* **35** (6), 913–916. https://doi.org/10.1080/07900627.2019.1670506.

Brewis, A., Roba, K. T., Wutich, A., Manning, M. & Yousuf, J. 2021 Household water insecurity and psychological distress in eastern Ethiopia: Unfairness and water sharing as undertheorised factors. *SSM – Mental Health* **1**, 100008. https://doi.org/10.1016/j.ssmmh.2021.100008.

Bulled, N. 2017 The effects of water insecurity and emotional distress on civic action for improved water infrastructure in rural South Africa. *Medical Anthropology Quarterly* **31** (1), 133–154. https://doi.org/10.1111/maq.12270.

Everitt, B. & Hothorn, T. 2011 *An Introduction to Applied Multivariate Analysis with R*. Springer Science & Business Media, New York, USA.

Haseena, M., Malik, M. F., Javed, A., Arshad, S., Asif, N., Zulfiqar, S. & Hanif, J. 2017 Water pollution and human health. *Environmental Risk Assessment and Remediation* **1** (3). https://doi.org/10.4066/2529-8046.100020.

Isaacman, A. & Musemwa, M. 2021 Water security in Africa in the age of global climate change. *Dædalus* **150** (4), 7–26. https://doi.org/10.1162/daed_e_01870.

Kangmennaang, J. & Elliott, S. J. 2021 Linking water (in)security and wellbeing in low-and middle-income countries. *Water Security* **13**, 100089. https://doi.org/10.1016/j.wasec.2021.100089.

Kangmennaang, J., Bisung, E. & Elliott, S. J. 2020 'We are drinking diseases': Perception of water insecurity and emotional distress in urban slums in Accra, Ghana. *International Journal of Environment Research and Public Health* **17** (3). https://doi.org/10.3390/ijerph17030890.

Lewis, E. W., Siyambango, N. & Lendelvo, S. 2018 Assessment of accessibility of safe drinking water: A case study of the Goreangab informal settlement, Windhoek, Namibia. *Water Practice & Technology* **13** (4), 871–878.

Livingston, J. 2021 Water scarcity & health in urban Africa. *Dædalus* **150** (4), 85–102. https://doi.org/10.1162/daed_a_01874.

Mao, F., Miller, J. D., Young, S. L., Krause, S., Hannah, D. M., Brewis, A. & HWISE Research Coordination Network 2022 Inequality of household water security follows a Development Kuznets Curve. *Nature Communications* **13** (1), 4525. https://doi.org/10.1038/s41467-022-31867-3.

Mason, L. R. 2014 Examining relationships between household resources and water security in an Urban Philippine Community. *Journal of the Society for Social Work and Research* **5** (4), 489–512. https://doi.org/10.1086/678923.

Meehan, K., Jurjevich, J. R., Chun, N. M. J. W. & Sherrill, J. 2020 Geographies of insecure water access and the housing–water nexus in U.S. cities. *Proceedings of the National Academy of Sciences* **117** (46), 28700–28707. https://doi.org/10.1073/pnas.2007361117.

Motho, M., Kolawole, O. D., Motsholapheko, M. R. & Mogomotsi, P. K. 2022 Influence of household demographic and socio-economic factors on water demand in Ngamiland District, Botswana. *Water Science* **36** (1), 48–59. https://doi.org/10.1080/23570008.2022.2048581.

Nounkeu, C. D. & Dharod, J. M. 2019 Status on the scale development to measure water insecurity experiences at the household level: A narrative review. *Advances in Nutrition* **10** (5), 864–875. https://doi.org/10.1093/advances/nmz008.

Paudel, S., Kumar, P., Dasgupta, R., Johnson, B. A., Avtar, R., Shaw, R., Mishra, B. K. & Kanbara, S. 2021 Nexus between water security framework and public health: A comprehensive scientific review. *Water* **13** (10), 1365. https://doi.org/10.3390/w13101365.

Postigo, C., Martinez, D. E., Grondona, S., Miglioranza, K. S. B., 2018 Groundwater pollution: Sources, mechanisms, and prevention. In: *Encyclopedia of the Anthropocene* (Dellasala, D. A. & Goldstein, M. I., eds). Elsevier, pp. 87–96. https://doi.org/10.1016/B978-0-12-809665-9.09880-3.

R Core Team, R. 2022 *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria.

Scott, D., Iipinge, K. N., Mfune, J. K., Muchadenyika, D., Makuti, O. V. & Ziervogel, G. 2018 The story of water in Windhoek: A narrative approach to interpreting a transdisciplinary process. *Water* **10** (10), 1366. https://doi.org/10.3390/w10101366.

Shikongo, A. 2020 Cases of typhoid fever detected in Namibia. *The Namibian*. Available from: https://www.namibian.com.na/198938/archive-read/Hepatitis-E-continues-tospread (accessed 24 April 2022).

Shikongo, A. 2022 Cases of typhoid fever detected in Namibia. *The Namibian*. Available from: https://www.namibian.com.na/6218439/archive-read/Cases-oftyphoid-fever-detected-in-Namibia (accessed 24 April 2022).

van den Berg, R., Otto, B. & Fikresilassie, A. 2021 *As Cities Grow Across Africa, They Must Plan for Water Security*. World Resources Institutes. Retrieved from 25 February. Available from: https://www.wri.org/insights/cities-grow-across-africa-they-must-plan-water-security (accessed 16 June 2022)..

van Rensburg, P. & Tortajada, C. 2021 An assessment of the 2015–2017 drought in Windhoek. *Frontiers in Climate* **3**, 602962.

Wutich, A. 2020 Water insecurity: An agenda for research and call to action for human biology. *American Journal of Human Biology* **32** (1), e23345. https://doi.org/10.1002/ajhb.23345.

Young, S. L., Frongillo, E. A., Jamaluddine, Z., Melgar-Quiñonez, H., Pérez-Escamilla, R., Ringler, C. & Rosinger, A. Y. 2021a The importance of water security for ensuring food security, good nutrition, and well-being. *Advances in Nutrition* **12** (4), 1058–1073. https://doi.org/10.1093/advances/nmab003.

Young, S. L., Miller, J. D., Frongillo, E. A., Boateng, G. O., Jamaluddine, Z. & Neilands, T. B. 2021b Validity of a four-Item household water insecurity experiences scale for assessing water issues related to health and well-being. *American Journal of Tropical Medicine and Hygiene* **104** (1), 391–394. https://doi.org/10.4269/ajtmh.20-0417.

Zerbo, A., Delgado, R. C. & González, P. A. 2020 Vulnerability and everyday health risks of urban informal settlements in Sub-Saharan Africa. *Global Health Journal* **4** (2), 46–50. https://doi.org/10.1016/j.glohj.2020.04.003.

Zheng, M., Wutich, A., Brewis, A. & Kavouras, S. 2022 Health impacts of water and sanitation insecurity in the Global North: A scoping literature review for U.S. colonias on the Mexico border. *Journal of Water and Health* **20** (9), 1329–1342. https://doi.org/10.2166/wh.2022.085.

First received 5 April 2023; accepted in revised form 15 July 2023. Available online 31 July 2023