

Water, Sanitation and Diarrhoeal Diseases in Nouakchott (Mauritania): Analysing the Determinant of Urban Health Inequalities

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Abstract

The lowest access to water and sanitation services in the city of Nouakchott leads to several practices and behaviours that create a social-ecological system which increasing risk of waterborne diseases transmission like diarrhoea. Using environmental, socio-economic and epidemiologic indicators from national statistic services, this study aims to assess the impact of Nouakchott's social-ecological system on diarrhoeal diseases with particular emphasize on vulnerability to environmental health risks according to water and sanitation status. The results showed that respectively 25.6% and 69.8% of households had access to improved water sources and latrines with a large variability according to municipalities. The diarrhoeal morbidity (12.8%) was higher in dense urban areas where the lack of water supply and sanitation facilities affected mainly poor households (20.8% of the population). However, diarrhoeal risk is spatially variable in accordance to environmental sanitation disparities with a rate rising from 9.1% in municipalities with high level of improved water and latrines to 19.1% in communities with a lower level of ecosystem services. The correlation analysis between socio-economic, environmental and epidemiological variables reveals significant associations. Thus, the dynamic of social-ecological system demonstrated that environmental factors linked to unimproved drinking water sources and sanitation services were the main driver of diarrhoeal diseases transmission in some municipalities. The reality of the linkage between health risks due to diarrhoea and urban environmental conditions addresses the issues of the Sustainable Development Goals (SDG) Health and Wellbeing and Water and Sanitation services in Mauritania context.

Keywords: Water; Sanitation; Hygiene; Diarrheal diseases; Health risks; Nouakchott; Mauritania

Introduction

Unsafe water and inadequate sanitation associated to poor hygiene are main drivers for transmission of faecal-oral diseases, including diarrhoea considered as most important public health concern in developing countries [1]. Today, 900 million persons do not have access to safe drinking water and 2.5 billion lacked basic sanitation [2]. Despite the United Nations interventions within the Millennium Development Goals (MDGs) and accomplished progresses, targets are not yet met in Sub-Saharan Africa countries [3]. However, access to drinking water and sanitation services is a fundamental for living conditions improvement, fighting against many transmissible diseases and health status. Although easily preventable, diseases related to water, sanitation and hygiene remains one of the most serious child health problems worldwide [4]. An unhealthy environment poses a major health risks particularly in a context where lack of improved water and sanitation facilities is worsened by poverty incidence. Every year, 1.8 million people, die from diarrhoeal diseases (including cholera). Globally, 90% of the mortality burden affect children under 5 years living mostly in developing countries and 88% of the morbidity is

attributable to poor water quality, inadequate sanitation and precarious hygiene [5,6]. Diarrhoea alone is responsible for 5,000 infant deaths per day throughout the world and children in developing countries suffer from 5 to 6 diarrhoeal episodes per year [7,8].

Located on the coast front of the Mauritanian desert, Nouakchott (850,000 inhabitants) provides a clear example of semi-arid and Sahelian cities facing to water supply and sanitation services challenges. Experiencing rapid urban growth requiring the planning of drinking water and sanitation networks, this city is confronted to a critical environmental sanitation affecting mainly poor neighbourhoods [9]. In accordance with the Multiple Indicators Cluster Survey [10], only 30.5% of households have improved water source (tap or fountain) and 78.5% use adequate sanitation. A large majority of inhabitants resort to use unimproved water sources (such as wells or purchasing from water tanks and carts) and inadequate sanitation facilities (public latrine, open air defecation). The large presence of unsafe water supply points in highly polluted environment context due to the lack of basic hygiene increases the risk of water contamination and vulnerability to health risks [11]. Moreover, rainwater and wastewater accumulation in urban areas highlights the inadequate sanitation particularly in municipalities densely populated. Thus, the interplay between water and sanitation deficiencies creates a social and ecological system (Figure 1) favourable to pathogens

propagation and diarrhoea transmission in this particular urban context [12-14].

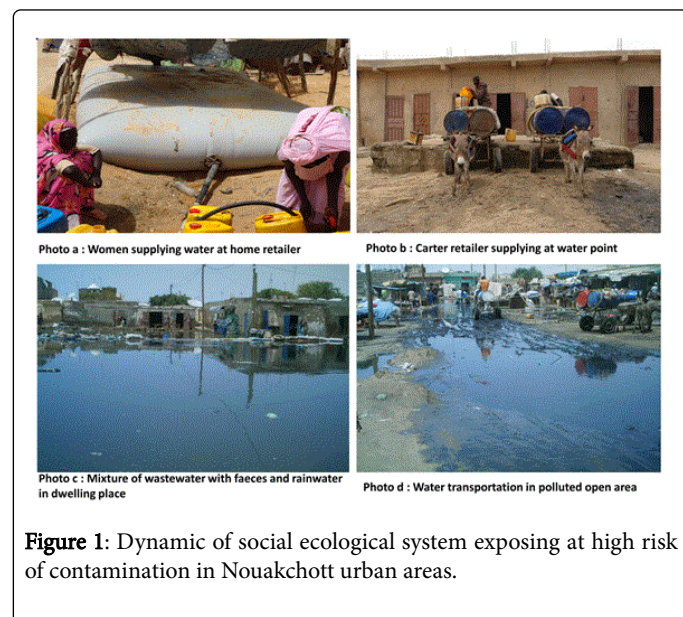


Figure 1: Dynamic of social ecological system exposing at high risk of contamination in Nouakchott urban areas.

Hence, the dynamic relationship between social-ecological system related to environmental sanitation conditions and urban epidemiological status explains the importance of diarrhoeal diseases in Nouakchott global burden morbidity. According to the Multiple Indicators Cluster Survey Report (MICS), the prevalence of diarrhoeal diseases in Nouakchott is 21.9%. This burden rate is much higher than the national urban average of 20.6% [10]. However, this global epidemiological situation masks great health inequalities at city level due to the fact that diarrhoeal diseases affect individuals, communities and areas differently [15,16].

The high burden of health risks associated to lack of safe drinking water and sanitation demonstrate that progress accomplished within the Millennium Development Goals has been insufficient to impact significantly on reduction of diarrheal diseases morbidity and mortality [2]. Then, the aim of this contribution is to investigate the interplay between water, sanitation, hygiene and health in order to improve the effectiveness of environmental sanitation and health interventions by giving foundation for Sustainable Development Goal (SDG) achievement.

Methods

Conceptual framework

Within an international research program, NCCR-North South (National Centre of Competence in Research North-South), we build a multidisciplinary research group addressing the issues of environmental sanitation, health and well-being in disadvantaged urban areas. This approach of research group is founded in the concepts of vulnerability and resilience to health risks to develop a systems-thinking through close collaboration between different disciplines, such as medicine, epidemiology, public health, ecology, geography, climatology, anthropology, sociology, economics and political science for better health and well-being improvement of vulnerable communities [17,18]. Following the conceptualization of vulnerability and resilience, results presented in this paper is the

contributive output from the multidisciplinary research group to make a first statement step for more comprehensive finding of health and environmental sanitation interlinkages in Nouakchott urban areas.

Study area

The study area was the city of Nouakchott which is the national capital of Mauritania. Urban population was estimated at 850,000 inhabitants in 2009 [19], unequally distributed among the nine municipalities aggregated under the Nouakchott Urban Community (NUC). Then, study area covers all the 9 municipalities of Nouakchott Urban Community.

Data collection

Using various sources (surveys, studies and reports, digital maps), socio-environmental and epidemiological data were compiled and aggregated at municipality scale. With data collected, the indicators primarily generated at municipality level were subsequently used for statistical analysis and mapping.

Socio-environmental data

The National Statistical Office (NSO) of Mauritania conducted a national survey Living conditions and poverty in 2008-2009 integrating indicators of various modes of potable water supply and sanitation facilities. The socio-environmental data used in this paper come from the permanent survey on living conditions of households collected at the municipality level throughout the national territory. This important survey realized in two rounds covered 13,705 households with relevant information in the access, use and satisfaction of population concerning key exosystemic services (water, sanitation, hygiene, soil, air, etc.). The indicators on access to drinking water, sanitation facilities and socio-economic aspects treated in this contribution are given at the municipality level. More than half of the households of the survey sample live in Nouakchott. These quantitative data were completed by qualitative information from results studies developed by the Nouakchott Urban Community, mainly on water and sanitation issues but also including collection of water points and wastewater discharge points (GPS) recorded by the research team. A digital map database of Nouakchott was obtained from the department of spatial planning and regional action of Mauritania, which was readily available from 2010 at a scale of 1:10,000.

Epidemiological data

Epidemiological data were obtained from the health information system of the regional delegation for health action of Nouakchott and indicators collected concern mainly diarrhoeal diseases. Epidemiological data of diarrhoea consisted in compilation of reports from health information records at healthcare facilities. Each municipality disposes three health centres. Data are readily available at the city health centres, which lists the number of aggregated cases in routine reports from different health centres. The number of diarrhoeal episodes was used to estimate the prevalence of this pathology per municipality. Diarrhoea diseases concern reported cases by clinicians which refer to WHO definition considering at latest three emissions loose or watery stools in one day.

Data analysis

Data were analysed using SPSS software version 18 for the estimation of frequencies, calculation of correlations between epidemiological and socio-environmental variables and mapping the resulting output.

A descriptive statistical analysis was realized to generate relevant indicators on water sources, water quality and prevalence of diarrhoea. A cross-analysis (intermediate correlation matrix) of socio-environmental and epidemiological variables was carried out to identify risk factors linked to the development of diarrhoea and investigate the spatial disparities of disease prevalence. The correlations between water supply modes, sanitation systems, socio-economic status and diarrhoeal morbidity were investigated using principal component analysis (PCA).

With the digital map available at the municipality level, socio-environmental and epidemiological indicators generated were mapped using geospatial techniques, including diarrhoeal prevalence, unimproved water sources and unimproved latrines, with ArcGIS software (ESRI) version 10. An environmental cartography of risk factors was developed by mapping water points and wastewater discharge to evaluate health risks vulnerability of communities to environmental sanitation status. These spatial indicators were collected by GPS Garmin 92.

Results

Socio-spatial variability in poor access to water and sanitation services

Socio-environmental results (Figure 2) show that only 25.6% of households had access to improved water sources (indoor tap, neighbouring tap, and fountain) and 69.8% to appropriate latrines (sewerage system, private septic tanks and dry sanitation). The lowest access to drinking water engages a large majority (74.4%) of households to water points as domestic supplying mode (Figure 3a) while almost a third of population (30.2%) use inadequate facilities and practice open areas wastewater discharge (Figure 3b). In fact, the percentage of population with household connections to sewerage system is lowest in Nouakchott urban area. However, there is large socio-spatial variability in access and availability of environmental sanitation services depending on geographical area location. The social-ecological context in process highlights that household with unimproved drinking water sources and sanitation facilities mainly live in municipalities with low socio-economic status (Figure 2). Consequently, the lack of potable water supply and improved sanitation affect more municipalities with a higher concentration of poor communities (Figure 2), such as Riyadh (53.4%) and Dar-Naim (36.9%) with monthly an average income per household of 200 US dollars approximately. Overall, 35% of the population uses about 78% of the distributed volume of drinking water (approximately 100 L/person/day) while the other two-thirds share the rest (approximately 15 L/person/day).

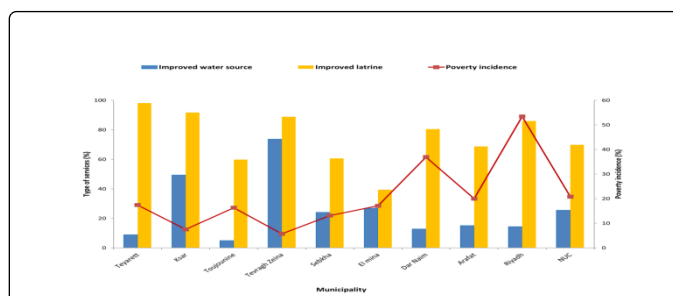


Figure 2: Type of water source supply and sanitation modes of households according to the socio-economic status in municipalities of Nouakchott, Mauritania, 2009.

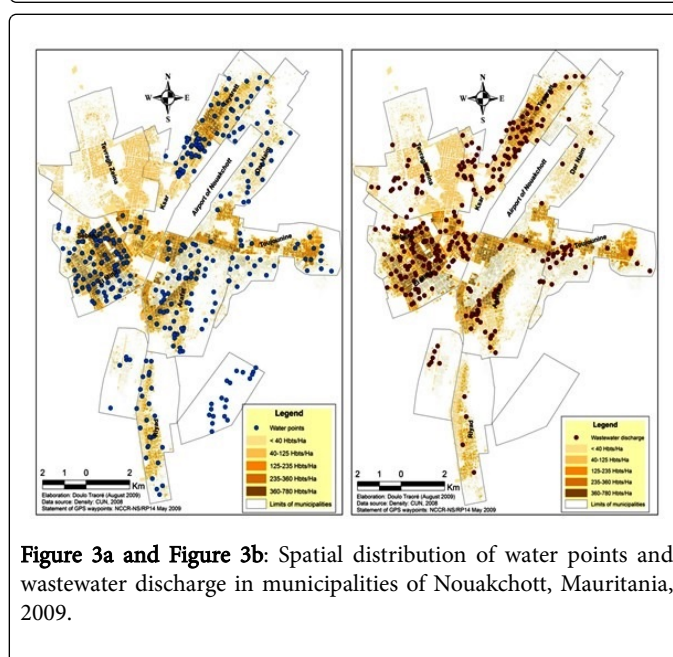


Figure 3a and Figure 3b: Spatial distribution of water points and wastewater discharge in municipalities of Nouakchott, Mauritania, 2009.

Diarrhoeal morbidity most frequent in children under 5 years in vulnerable communities

With a prevalence average of 12.8%, diarrhoea is the second most common reason for healthcare recourse after acute respiratory infections (Table 1). The morbidity varies in accordance to municipality and exposed social group. Gradually, prevalence burden is higher than urban average in the municipalities of Sebkh (19.1%), El Mina (16.6%), Riyadh (14.3%) and Teyarett (13.8%), characterized by the predominance of poor housings and more vulnerable communities (Table 1). Large part of diarrhoeal burden registered affects children under 5 years (51.6% of total number of cases), particularly in the municipalities of Arafat (61.2%), El Mina (58%), Teyarett (58%) and Dar-Naim (57.8%) (Table 1).

Municipality	Global prevalence	Children under 5 years	Children aged 5-14 years	Individuals aged over 14 years
Teya rett	13.8	58.0	17.7	24.3

Ksar	13.5	47.1	18.9	33.9
Toujour ine	10.3	49.1	16.7	34.3
Tevragh Zeina	9.1	51.5	10.8	37.7
Sebkha	19.1	35.3	19.5	45.2
El Mina	16.6	58.0	15.4	26.6
Arafat	10.2	61.2	12.4	26.4
Da r Na im	12.4	57.8	11.1	31.0
Riyadh	14.3	47.1	17.5	35.4
N UC	12.8	51.7	14.1	34.2

Table 1: Distribution of diarrhoeal incidence according to age in municipalities of Nouakchott, Mauritania, 2009.

Interplay between diarrhoeal diseases and risk factors

Interactions of determinants as type of water supply source, sanitation system and socio-economic status provide foundation for explanation of diarrhoeal diseases prevalence. The overlaying maps in Figures 4a and 4b show the magnitude of diarrhoeal morbidity according to the distribution of unimproved water sources and sanitation services considered as main risk factors varying greatly between municipalities. Regarding drinking water supply, diarrhoea morbidity evolves progressively in relation with the importance of unimproved water particularly in the municipalities of Teyarret, Sebkha and El Mina. In the domain of sanitation issue, diarrhoeal prevalence increases according to the magnitude of households without improved latrines in municipalities, particularly in Sebkha and El Mina (Figure 4a and Figure 4b).

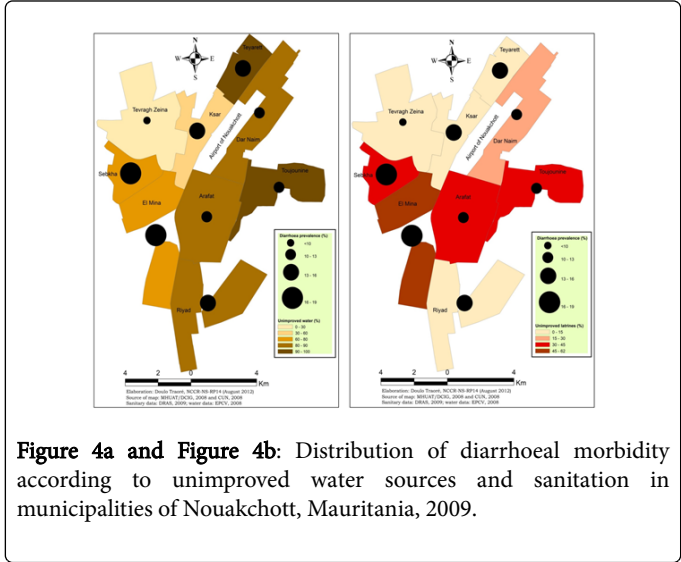


Figure 4a and Figure 4b: Distribution of diarrhoeal morbidity according to unimproved water sources and sanitation in municipalities of Nouakchott, Mauritania, 2009.

Correlation matrices confirm this observation, although a range of risk factors may be associated to diarrhoea transmission including the water supply source, mode of sanitation and socio-economic status (Table.2). Access to potable water ($R=-0.187$) combined with improved latrines ($R=-0.402$) play as resilient factors to diarrhoeal risk (Table 2). Untreated stored water ($R=0.429$), unimproved latrines ($R=0.461$) and discharged wastewater ($R=0.569$) seems as vulnerability factors to diarrhoeal diseases (Table 2). Significantly, diarrhoea prevalence is higher in municipalities concentrating most of the unimproved water sources, inadequate sanitation devices and low socio-economic status households are located. Water and hygiene practices are mostly governed by socio-economic status as showed by the matrix of correlation (Table 2) and the PCA which illustrates the interactions and the proximity between similar variables (Figure 5).

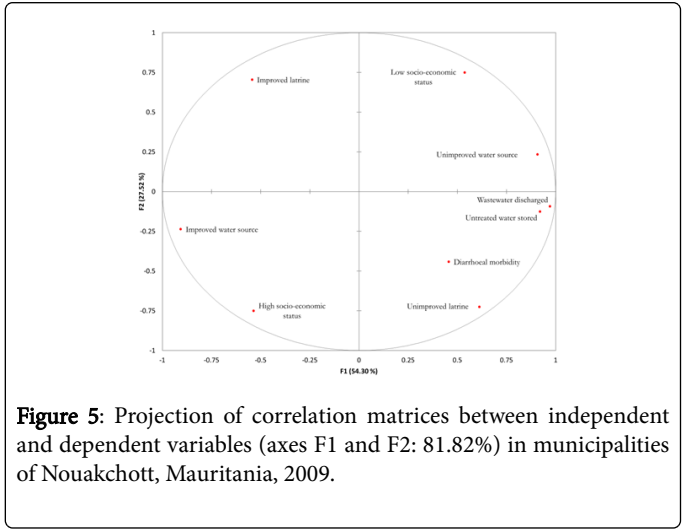


Figure 5: Projection of correlation matrices between independent and dependent variables (axes F1 and F2: 81.82%) in municipalities of Nouakchott, Mauritania, 2009.

Variables	Improved water source	Unimproved water source	Untreated water store	Improved latrine	Unimproved latrine	Wastewater discharged	BW socio economic status	High socio economic status	Diarrhoeal morbidity
Improved water source	1								

Unimproved water source	-1.000	1							
Untreated water stored			1						
Improved latrine	0.241	-0.241	-0.633	1					
Unimproved latrine					1				
Wastewater discharged						1			
BW socio economic status							1		
High socio economic status	0.536	-0.536	-0.469	-0.110	0.145	-0.299	-1.000	1	
Diarrhoeal morbidity	0.187	0.188	0.429	-0.402	0.461	0.569	-0.007	0.007	1

Table 2: Matrices of correlation between observed variables (Pearson (n)) according to municipalities in Nouakchott, Mauritania, 2009.

Discussion

Considering the perspective of environmental health related urban well-being, this study provided a valuable contribution to understand relationship between sources of water supply, modes of sanitation, socio-economic status and diarrhoeal morbidity. Urban services such as drinking water and sanitation are considered as an essential component of individual and collective hygiene [20,21]. The correlation between socio-ecological and epidemiological data offers a comprehensive view of the links between these environmental sanitation services and the level of diarrhoeal morbidity that are also characterized by spatial and social heterogeneity. Diarrhoeal disease risk is also aggravated by the quality of drinking water (part of water network, water points, taps and basins) compromised by faecal contamination due to the lack of standards for sanitation facilities installation in homes according to WHO guidelines [11,22,23]. According to the results of 150 public water points randomly sampled and tested by bacteriological service of INRSP, 93% were contaminated with coliform bacteria averaging between 10 to 80 coliform per 100 ml. Even higher rates were observed in the municipalities of Sebkha, El Mina, Arafat, Riyadh and Teyarett. This water contamination phenomenon is so critical that only 50.9% of households use appropriate methods for drinking water treatment [10].

The low availability of improved latrines in large part of households and the absence of safe sewage systems generate an open air defecation practices and wastewater discharge in urban public areas. Globally, the proportion of households using both improved water sources and sanitation is still very low with an average of 26.3%. Thus, the occurrence of diarrhoeal disease appears as consequence of the particular socio-ecological system resulting from the complex relationship between water supply source, sanitation and hygiene practices [1,22,24]. When environmental risk factors are lower, diarrhoeal prevalence decreases significantly. Populations with access to piped water and living in a healthy environment are less affected by diarrhoeal disease risks. Moreover, people whose main source of drinking water comes from a cart water dealer or a collective water point are three times more exposed to diarrhoea risk than residents with water tap at home [23]. The same observation is also valid for

sanitation with diarrhoeal morbidity being two times greater in municipalities concentrating highest number of households without improved latrines.

Spatially, diarrhoeal morbidity seems to be located in urban areas registering more households with a low socio-economic status, without improved sources of drinking water and adequate sanitation facilities, highlighting the importance of exposition to health risks [25,26]. The magnitude of disease is greater in disadvantaged neighbourhoods where people are mainly supplied from water points such as water carts and where improved latrines are typically lacking. This specific social-ecological system processing explains that environmental sanitation factors are the main driver of diarrhoeal diseases transmission [1,5]. Water and sanitation have a direct impact on hygiene and health improvements while their availability within communities increase good hygiene practices [23,27].

The last Joint Monitoring Programme (JMP 2015) report shows that Mauritania did not meet the targets but accomplished good progress for gaining access to improved drinking water (58%) and moderate progress for sanitation (58%) in urban areas since 1990 [28]. Despite the achievements of the MDG period, a great deal remains to be done. Behind the global headline progress, huge disparities in access remain around urban areas. While many municipalities have now achieved universal access, improved drinking water sources and sanitation coverage varies widely in urban areas with the lowest levels of progress particularly in poor neighbors and communities. In this perspective, the city could represent a factor of health degradation instead of being an area promoting well-being of inhabitants. Bridging the gap between research, innovation and practice need to drive best science to produce relevant knowledge by decrypting the complexity of drinking water, sanitation, hygiene and health relationship with careful attention to spatial inequalities and vulnerable zones [29]. Knowledge production addressing the issue of drinking water and sanitation access will facilitate the effective achievements of the Sustainable Development Goal (SDG) within the 2030 world agenda by highlighting clearly targeting priority areas. A conceptual modelling approach to health related urban well-being and geographical demarche can support

interventions of SDG 3 (Health and Well-being) and 6 (water and sanitation) in developing cities [30].

Conclusion

The predominance of unimproved drinking water source associated to the increase risk of contamination with different hygiene practices and the presence of poor sanitation gives rise to ecological conditions favourable to pathogens circulation in urban areas.

Lack of potable water and poor sanitation facilities increasing bad hygiene practices appeared to be the main routes of diarrhoeal diseases transmission. The magnitude of linkage is considered to be a main challenge of urban health, particularly for children under 5 years as demonstrated in the city of Nouakchott. The higher concentration of unimproved water supply affect more children under 5 years in the municipalities of Teyarett, El Mina, Arafat and Dar-Naim while lack of sanitation exposed more individuals aged over 14 years especially in the areas of Sebkha and Toujounine. Hence, the unequal distribution of diarrhoeal morbidity appears to be determined by the relationship between water supply mode and sanitation system elucidating the high prevalence in municipalities with more unimproved water sources as well as households without adequatelatrines.

Moving from MDG to SDG achievements within the 2030 world agenda, the finding of urban health foundation through drinking water and sanitation services seems a great support to improve well the awareness of decision making regarding WASH challenges to cut transmission chain of faecal-oral diseases and contribute to better global health in urban areas.

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References

- Bartram J, Cairncross S (2010) Hygiene, sanitation, and water: forgotten foundations of health. *PLoS Medecine* 7: e1000367.
- UNICEF, WHO (2012) Progress on Drinking Water and Sanitation. Update 2012, Joint Monitoring Programme 68.
- Hunter PR, MacDonald AM, Carter RC (2010) Water supply and health. *PLoS Medecine* 7: e1000367.
- Cairncross S, Bartram J, Cumming O, Brocklehurst C (2010) Hygiene, sanitation, and water: what needs to be done? *PLoS Medecine* 7: e1000365.
- UNICEF, WHO (2009) Diarrhoea: Why children are still dying and what can be done. WHO 68.
- Murray CJL, Vos T, Lozano R, Naghavi M, Flaxman AD, et al. (2012) Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet Infect Dis* 380: 2197-2223.
- Umesh D, Bresee JS, Glass RI (2003) The global burden of diarrhoeal disease in children. *Bulletin of the World Health Organisation* 81: 236-237.
- Lozano R, Naghavi M, Foreman K, Lim S, Shibuya K, et al. (2012) Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet Infect Dis* 380: 2095-2128.
- Salem G (1998) La santé dans la ville. *Géographie d'un espace dense : Pikine (Sénégal)*. Karthala 360.
- NSO (2008) Enquête par grappes à Indicateurs Multiples (MICS). Suivi de la situation des enfants et des femmes. Rapport final, Office National de la Statistique (NSO), Nouakchott, Mauritanie 221.
- CUN INRSP (2009) Evaluation de la qualité physico-chimique et bactériologique de l'eau des différents circuits d'approvisionnement à Nouakchott (Mauritanie). Rapport d'étude, Communauté. Nouakchott 25.
- WSP (2012) Impacts socio-économiques d'un mauvais assainissement en Afrique. Etude documentaire sur la Mauritanie. Water and Sanitation Programme 6.
- Sy I, Koita M, Traoré D, Keita M, Lô B, et al. (2011) Vulnérabilité sanitaire et environnementale dans les quartiers défavorisés de Nouakchott (Mauritanie): analyse des conditions d'émergence et de développement de maladies en milieu urbain sahélien. *Vertigo* 11: 17.
- Gagneux S, Schneider C, Odermatt P, Cissé G, Tanner M (1999) La diarrhée chez les agriculteurs urbains de Nouakchott en Mauritanie. *Med. Trop* 59: 253-259.
- Fewtrell L, Kaufmann RB, Kay D, Enanoria W, Haller L, et al. (2005) Water, sanitation and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *Lancet Infect Dis* 5: 42-52.
- Tumwine JK, Thompson J, Katua Katua M, Muiwajuzi M, Johnson Porras I (2002) Diarrhoea and effects of different water sources, sanitation and hygiene behavior in East Africa. *Trop Med Int Health* 7: 750-756.
- Sy I, Schwärzler P, Kouadio AS (2010) Global change and sustainable development: a synthesis of regional experiences from research partnerships. Perspectives of the Swiss National Centre of Competence in Research (NCCR) North-South, University of Bern. *Geographica Bernensia*, Bern 3: 33-46.
- Traoré D, Sy I, Utzinger J (2013) Water quality and health in Sahelian semi-arid urban context: geographical approach in Nouakchott (Mauritania). *Geospat Health* 8: 53-63.
- NSO (2009) Profil de la pauvreté en Mauritanie. Rapport final de l'Enquête Permanente sur les Conditions de Vie. National de la Statistique 173.
- Kjellstrom, T, Mercado S, Satterthwaite D, McGranahan G, Friel S, et al. (2007) Our cities, our health, our future: Acting on social determinants for health equity in urban settings. Report to the WHO 70.
- WHO, UN Habitat (2010) Hidden cities: unmasking and overcoming health inequalities in urban settings. WHO-UN-Habitat Report 145.
- Sy, Schwärzler p, kouadio AS, Kablan C (2010) An Interdisciplinary Approach of Vulnerability and Resilience to Health Risks in Underprivileged Urban Contexts in West Africa. *Glob Environ Change* 5: 33-46.
- Clasen Th F, Haller L (2008) Water Quality Interventions to Prevent Diarrhoea: Cost and Cost Effectiveness. Public Health and the Environment, World Health Organization 40.
- Sy I, Handschumacher P, Wyss K, Piermay JL, Lô B, et al. (2010) Variabilité des maladies diarrhéiques chez les enfants de moins de 5 ans en milieu urbain : l'exemple de Rufisque au Sénégal. *Médecine Tropicale* 70: 57-62.
- Nguendo Yongsy B, Salem G, Bruneau JC (2008) Epidémiologie géographique des maladies diarrhéiques à Yaoundé (Cameroun). *Moppemonde* 89: 17.
- Obrist B, Cissé G, Koné B, Dongo K, Granado S, et al. (2006) Interconnected Slums: Water, Sanitation and Health in Abidjan, Côte d'Ivoire. *Eur Dev Res* 18: 319-336.
- Dos Santos S, Legrand TK (2007) Accès à l'eau et mortalité des enfants à Ouagadougou (Burkina Faso). *Environ Risques & Santé* 6: 365-371.
- UNICEF, WHO (2015) 25 years Progress on Sanitation and Drinking Water. 2015 Update and MDG Assessment, Joint Monitoring Programme 90.
- Koné B, Feagan M, Houenou YA, Brou N, Houenou PV, et al. (2011) Facilitating the Relationship between Researchers and Policy-Makers: Experiences from three Ecohealth Projects in West and Central Africa. *Ecohealth* 8: 413-417.

30. Szombathely M, Albrecht M, Antanaskovic D, Augustin J (2017) A conceptual modeling approach to health-related urbanwell-being. Urban Sci 1: 17.