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WATER QUALITY AND WATERBORNE DISEASE ALONG THE NIGER RIVER, MALI: A STUDY OF LOCAL KNOWLEDGE AND RESPONSE

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A STUDY OF LOCAL KNOWLEDGE AND RESPONSE

By

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ABSTRACT

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Water Quality and Waterborne Disease along the Niger River, Mali:
A Study of Local Knowledge and Response

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This paper presents the findings of a study to assess patterns in local knowledge of and response to water quality and waterborne diseases in relation to seasonal changes in the Niger River Inland Delta. The study draws on field data collected in four villages along the Niger River in the Mopti district of Mali during September 2008. The major findings suggest: (1) water use behaviors and diarrheal disease management are influenced by the tremendous seasonal fluctuations in the riverine environment; (2) local awareness of the relationship between poor water quality, oral-fecal disease transmission, and waterborne disease is low; (3) interventions to mitigate the high incidence of childhood diarrhea and degraded water quality are limited by ongoing socio-economic, cultural, and institutional factors; and (4) women's level of health knowledge is socially and culturally dependent.

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TABLE OF CONTENTS

INTRODUCTION

Childhood diarrhea is a major public health concern and the leading cause of childhood mortality in much of the developing world. Globally, diarrheal disease accounts for nearly 1.6 million of the 10 million children under the age of five who die needlessly each year. In Mali, the focus of the study presented herein, diarrheal disease accounts for approximately 27,720 or 22% deaths annually of children in their first 5 years of life (Bryce et al., 2006)[i]. Research demonstrates that many of these deaths can be prevented through simple and economical interventions in water supply provision, hygiene education, and basic sanitation provision (Banda et al., 2007; Easterly, 2006; Fewtrell et al., 2005; Vincent, 2003; Boyce and Pittet, 2002; Quick et al., 1996). The provision of potable water and health education to communities has moved to center stage on the international development agenda and in the interventions of many non-governmental organizations and national governments (Gleitsmann et al., 2007; Narayan, 1993). Indeed, the Millennium Development Goals (MDG) underscore the critical water-sanitation-waterborne disease-child survival linkages with the goal of reducing by half the proportion of people without access to safe drinking water and sanitation by 2015 (UN, 2003).

In response to the MDG goals, the Malian government initiated in 2004 a Water and Sanitation Programme in order to identify and examine the measures required to ensure that these sectors perform at a level of achievement. The government has since taken several tangible steps to achieve the MDGs, including establishing public/private partnerships to improve the management of drinking water systems and the adoption of a national sanitation policy. To further address the MDG goals, the Malian government in 2009 held a "Water and Sanitation" sector review to assess the target goals and the achievability of those goals. The country intends to make access to drinking water and wastewater services one of the essential components of its approach to fighting poverty, reducing waterborne disease, and improving child health. Mali has set forth an objective even more ambitious than that defined in the MDGs, targeting an 82% rate of public access to drinking water by 2015. In order to succeed, 7,000 new water points must be built and 3,000 more need to be rehabilitated between 2010 and 2012 (UN, 2008). The required amount of spending to achieve this level of service provision over the next three years is estimated at 220 billion CFA francs (335 billion euros). To put this figure into perspective, it is worth noting that the entire Malian budget, including contributions from international aid, stands at roughly 1000 billion CFA francs (1,500 billion euros).

In the regional context of Africa, it is widely known and well-documented that insufficient water quantity, poor hygiene, lack of sanitation, and low levels of education are all contributing factors to the spread of waterborne diseases. In particular, the level of women's knowledge of health-related issues and awareness of healthful practices plays a key role in water management and childhood health (Andrzejewski et al., 2008; Singh et al., 2005; Hetzel et al., 2004; Omokhodion and Omokhodion, 2004; Ebong, 1994; Trykker et al., 1994; Dixson and Thompson, 1993). A study from Nigeria conducted in 1993 that entailed interviewing 2,000 people from four villages reported that the causes of malaria and of diarrhea were known by fewer than 10% of mothers in each village. The study also concluded that only 2% (one school teacher) of the surveyed population treated their drinking water, while drinking water resources were found to be generally inadequate (Dixon and Thompson, 1993). Another example that demonstrates misconceptions of waterborne disease comes from a study of knowledge of water quality and waterborne disease in rural Nepal (Pradhan et al., 2005). These researchers found that communities may often be unaware of the contaminants in local drinking water despite the high incidence of diarrheal diseases. A very different experience has been identified in the Mzingwane Catchment, Zimbabwe where Nare et al. (2006) found that local people had a widespread use of indigenous knowledge and practices regarding water quality based on smell, taste, color, and odor perceptions. Residents were generally more concerned about the physical parameters than the bacteriological quality of water. The study also concluded that local awareness of what caused water pollution and the effects of pollution on human health, crops, domestic animals, and aquatic ecology was generally high. The study suggests that "local knowledge systems could be integrated into the formal water quality monitoring system, in order to complement the conventional monitoring network (Nare et al., 2006, page 207)." With specific regards to Mali, however, there is little in the way of published data directly related to local knowledge of water quality of the Niger River and local knowledge of causality of waterborne disease.

Another critical factor influencing waterborne disease trends in Africa as well as elsewhere in the developing world is seasonality. For example, several studies have emphasized the correlation between the prevalence of diarrheal diseases and geographic variables such as climate (Anyamba et al., 2006; Lipp et al., 2002; Lawoyin et al., 1999) and especially rainfall (Findley et al., 2005). The relationship between seasonality and disease transmission is complex and can differ from one region to another in Mali depending upon the physioclimatic conditions of specific village locations. In many areas of Africa it is widely acknowledged that the transmission of gastro-enteritis peaks during the rainy season (Orlandi et al., 2001; Tomkins et al., 1989) because rainfall facilitates an increase of fecal contamination to water sources (Findley et al., 2005; Vaahtera et al., 2000; Musa et al., 1999; Brewster and

Greenwood, 1993; Tomkins 1981). Conversely, additional research in West Africa (Molbak, et al., 2000) and sub-Saharan Africa (Vargas et al., 2004; Steele et al., 2003; Georges et al., 1984) has shown that the peak in diarrheal dieses is during the dry season when water scarcity affects hygienic conditions and favors transmission via fecal-oral route (Weisberg, 2007). The differences in results may be due to subtle cultural and behavioral factors as well as climate variations. In other words, once seasonality is established in regards to the timing of highly infectious periods, then improved allocation of resources and intervention strategies can be in place before disease-prone seasons (Findley et al., 2005). Each climatically different region would need separate evaluations to correctly assess the seasonal height of diarrheal diseases.

This paper reports the results of a study of rural Malian mothers' knowledge, behavior and seasonal response to diarrheal diseases and the household management of water, hygiene and sanitation. The study draws on data collected from September 2008 in four villages along the Niger River in the Mopti region. The objectives of this study were to: (1) document mothers' collection, transport and storage of household water, drinking water quality, and family hygiene and sanitation practices in relation to hydrographic seasonal variability of the Niger River; (2) develop an understanding of mothers' knowledge of diarrheal diseases in terms of causality, perceived severity, and treatment of the disease and in relation to seasonality; (3) gain an understanding of the level of adoption of knowledge and practice taught by health officials in the region; and (4) identify potential and relevant linkages between women's water management and sanitation practices and disease transmission. The ultimate goal of the study was to collect data as part of a holistic process of working collaboratively with communities to reduce waterborne diseases. The information and results from this study are intended to be used to guide the development of water quality, hygiene and sanitation education in conjunction with interventions to improve water sources such as water filtration systems or a drilled well.

DEVELOPMENT INTERVENTIONS IN WATER AND DIARRHEAL DISEASE

To address the widespread and serious issues of diarrheal diseases, funding and efforts have gone into the implementation of interventions such as improved drinking water sources (e.g., wells and filters), hygiene education, and the provision of appropriate sanitation facilities. A vital question arises: Are these interventions effectively reducing childhood mortality rates? In a summary of the meta-analysis by Fewtrell et al. (2005) data was compiled from decades of health outcomes from various water quality interventions in developing countries around the world. The study concluded that interventions such as improved drinking water, improved sanitation, improved hygiene, and household water treatment all play an important role in the reduction of diarrheal diseases. One surprising piece of information from the study was the effectiveness of improved hygiene at reducing diarrheal disease-related mortality by 45% in some cases; in other situation improved drinking water sources only decreased the incidence of disease by 25%. Additional research shows that the mere availability of potable water and sanitation facilities is not enough to make a statistical difference in the reduction of diarrheal morbidity; hygienic behavior has a considerable impact on health (Pande et al., 2008; Cairncross et al., 2005; Fewtrell et al., 2005; Halvorson, 2004; Kolybine, 1992; Yacoob, 1991; White et al., 1972). A hygiene promotion component is therefore recommended as an adjunct to most water and sanitation projects in the developing world (WHO/UNICEF, 2000). While enormous funding is being allocated towards improving drinking water sources, resources might be better spent on hygiene improvement, particularly in the area of water hygiene and hand-washing (Pande et al., 2008; Cairncross et al., 2005; Fewtrell et al., 2005; Boyce and Pittet, 2002; WHO/UNICEF, 2000).

One reason for the failure of improved water sources to reduce diarrheal disease is that improvements to the water source often neglect the role of household storage and possible subsequent contamination. The recontamination of water at the household scale is well-documented (Banda, et al., 2007; Jensen, et al., 2002; Quick, et al., 1996). Households typically store water at home, and this water is vulnerable to contamination (primarily from handling) during transport and storage, regardless of how clean or uncontaminated the source originally is (Fewtrell et al., 2005). Further, another facet is that multiple interventions (i.e., hygiene education, sanitation facilities, water filter, etc.) do not have an additive benefit in reduction of disease (Fewtrell et al., 2005; Esrey et al., 1991). This has been explained in the "piecemeal implementation of more ambitious intervention programmes, which may result in an overall lack of focus or lack of sufficient attention being given to those components that are thought to be less central to the programme (typically, sanitation and hygiene education)" (Fewtrell et al., 2005, page 48). These authors suggest that future projects may benefit from multi-staged water improvement projects which first focus on community needs, concerns and adaptability of a project, followed by hygiene and sanitation classes, and lastly engineered drinking water interventions. Additionally, it is necessary to highlight that the impacts of an intervention depend on the local conditions and vary from community to community. Ultimately, interventions and implementation strategies in the context of water and health should be based on local priorities, knowledge, appeal, customs, feasibility, and cost-effectiveness as perceived by local stakeholders (Banda et al., 2007; Gleitsmann et al., 2007; Findley et al., 2005; Westaway and Viljoen, 2000).

MALI, WEST AFRICA: WATER, HEALTH AND POVERTY

The Republic of Mali is a landlocked country sharing borders with seven other countries. Mali has a population of 12 million people with a majority of its residents living in rural communities. Mali is one of the poorest economic countries in the world, with 51 % of the population living below the international poverty line (DHS, 2006) (Table 1). In 2008 Mali ranked 134th among 135 developing countries on the Human Development Index (UNDP, 2008). Infant, child and maternal mortality rates in the country remain among the highest in the world (DHS, 2006). The MDGs for Mali include a decrease in the child mortality rate from 196/1000 to 83/1000 by 2015 (UNICEF, 2007). This figure, if achieved, would represent a 57% decrease in childhood mortality to meet the MDG target, a steep goal for any country (Bryce et al., 2006). In 2004 the Government of Mali adopted the ambitious National Water Access Plan which aims to ensure that 75% of the population will have access to potable water by 2015 (Table 2). The National Department of Hydraulic Infrastructure (Directional National De Hydraulique or DNH) plans to achieve this lofty goal by implementing one improved or modernized water point in each village. This effort may include either digging a new well or upgrading an existing well to meet health standards. Non-governmental organizations (NGO) are skeptical of this national water plan. A statement from WaterAid (2005, 1-7), for example, notes:

> The County’s water resources far outweigh its needs, which should in theory mean that all water and sanitation needs can be catered for in the long term. Therefore, the real issue is the lack of mobilization and distribution to ensure these resources reach everyone including the poorest people.

The water sector faces massive funding challenges given the meager funding provided through the national budget, which has allocated 22% towards new and improved water sources. Approximately 80% of water sector investments come from external donors according to the

Deputy Director of DNH and the Technical Council on Water and Sanitation of the Ministry of Water (WaterAid 2005).

RESEARCH SETTING

This study was undertaken in September 2008 in the region of Mopti along the Niger River Inland Delta (Figure 1)[ii]. The Mopti region is primarily made up of small socio-cultural groups in rural villages situated along the banks of the Niger River. The area is rich in culture with deep roots in family and religious structure, yet relatively marginalized in terms of health, education, and economic development. At the time of this study the riparian zone was inundated by high stream flow induced by seasonal rainfall. Our study area included four villages along the Niger River and/or the adjacent rainy season inundation zone. The villages are small in population consisting of less than a few hundred people in each locale. The four village names and estimated[iii] number of households is as follows: Dangueri-Maliki (n=21), Bargon-Daga (n=100-200), Kobaka (n=30-60), and Danguere-Bila (n=30-60) (Figure 2). Danguere-Bila, Kobaka and Dangueri-Maliki are rural villages located on the west side of the Niger across from the city of Mopti (population 1,690,471 in 2006). Bargon-Daga is the only village of the four that is on the east side of the river and is located in a mixed urban-agricultural zone on the fringes of Mopti. An attempt was made to include all of the major ethnic groups present in the Mopti region in this study. As such, the ethnic breakdown by study site is as follows: Maliki and Bargon-Daga are Bozo communities; Kobaka is a Fulani settlement; and Danguere-Bila is a mixed community made up of Bozo and Bella.

These villages were selected as field sites for several reasons. First, a primary goal was to focus attention on village settings relatively similar to rural communities which are the place of residence for 73% of the country's population. Second, these four villages were accessible by boat or by car. Third, the women living in the villages are engaged in subsistence farming and fishing, both economic activities that serve as the primary means of livelihood for the majority of Malian women. The female illiteracy rate in Mali is 77% and as high as 81.5% in rural areas. The women who participated in this study were primarily illiterate with the exception of three women who had attended 1-3 years of school. Additionally, the villages are similar in terms of access to services and amenities in that they have no schools, no clinics or health workers, no electricity, and no stores or markets.

In the four villages, a range of water sources and water improvements are present. The village of Kobaka is the only village for several miles on the west side of the river that has an improved water source (well). The well was drilled in 2003 and is cement-encased with a hand pump. During the rainy season, the well becomes an island, and its base is submerged by water. On the other hand, Bargon-Daga on the east side of the river has a simple hand dug well. The well has an open shaft with a cement perimeter. Water is drawn out of the well with personal buckets brought by the villagers. There is a metal cover on the well, but it was not observed to be covering the well opening. The more typical scenario is that villages along the Niger River simply do not have access to improved water sources, and women draw water for domestic purposes directly from the Niger River. For example, the villages of Danguere-Bila and Dangueri-Maliki rely entirely on the river for their water supply. Women in these two villages without a well reported that there are times of year when they may walk several kilometers to Kobaka for well water. The cost per bucket is 5 CFA francs (0.01USD).

EFFECTS OF SEASONAL NIGER RIVER FLUCTUATIONS

This particular area of Mali is uniquely affected by fluctuations in the Niger River water levels in correspondence to seasonal rainfall. There is extreme variation in the amount and spatial distribution of rainfall in the African Sahel, in part, due to the dynamics of the northward moving Inter-Tropical Convergence Zone (ITCZ) during the summer and the local climatic variability in precipitation (Seiler et al., 2005). The longest reach of the Niger River (1,700 kilometers) extends through southern Mali. This portion of the river running through Mali is often referred to as the Niger River Inland Delta, and it is highly affected by annual variations in rainfall and consequential flow from the Niger River and the tributary of the Bani River. A population of 7.8 million lives in the Niger River basin, with a large percentage living along the river in villages or in the capital city of Bamako. Bamako's sanitation infrastructure has lagged far behind its rapid urban expansion, thereby adding to the pollution and water quality problems of the Niger River.

The Niger River Inland Delta receives about 200 to 600 mm of annual rainfall. South of Mopti the area corresponds to the Sahelian zone, while north of Mopti the climate can be characterized as semi-arid to arid. Mali has experienced a multi-decadal drought, which still persists; however, due to climatic variation, small bodies of water have increased in size, the grass cover has largely recovered, and in the lowlands there are signs of increased tree cover (Mougin et al., 2009). The rainfall regime is distinguish by a long dry season of about 9 months and a wet season of approximately 3 months, starting in July and lasting into September (Seiler et al., 2005). Rainfall is often hasty and fierce with intensities reaching sometimes 150 mm in only 2 to 3 hours (Diarra et al., 2004).

The Inland Delta is a dynamic seasonally-flooded ecosystem with abundant freshwater fishing areas, relatively productive pastureland, and fertile agricultural lands. The delta sustains productive irrigated agriculture, a sector that generates 590,000 tons of rice and 303,000 tons of sugar cane annually. The catches from freshwater fishing yield about 108,000 tons per year.

These figures depend on the water level and flooding in the Inland Delta (Seiler et al., 2005). Its excellent pastureland makes the Inland Delta a grazing region for more than 2 million head of cattle. The production of cotton covers an area of 122,000 square kilometers. In addition to the river's ability to give life to the land, it also serves as a transportation corridor for the movement of people to services (for example clinics, hospitals, schools and markets) and the transportation of goods to market.

The area around Mopti is characterized by a semi-arid tropical climate, with annual rainfall between 300 and 750 millimeters. There is a large fluctuation in river flow in accordance to seasonal variation. The rainfall from seasonal flux patters in the Upper Niger and Bani watersheds creates large seasonal variation in flows and the monthly distribution of runoff in the Inland Delta, with considerable variability between the 'dry' season and the 'wet' season. For six months (January through June) the low flow in the Niger River represents less than 8 percent of the total annual flow. An increase in precipitation beginning in May slowly contributes to the volume in the river, but the volume of water does not become significant until the seasonal rains arrive in July. Roughly 17 percent, 30 percent, and 25 percent of the total annual runoff is gained during the months of August, September, and October, respectively. Nearly 80 percent of the annual stream flow occurs between August and November (Seiler et al., 2005). The recession of flood waters is characterized by two phases and occurs rapidly and with regularity. The first phase of recession is in response to the depletion of surface water. The second phase is characterized by a rapid drop in base flow at the end of November in conjunction with the seasonal depletion of shallow aquifers. As a result, December through April can be a time of water scarcity for residents of this inland deltaic environment. Those living in this area adapt to the distinct seasonal patterns which dramatically affect their daily routines and habits. Seasonal variability on the Niger River changes the way people respond to health, hygiene and sanitation needs and concerns. Each community along the Niger River has unique and distinct ways of adapting and coping to seasonal variability.

DATA SOURCES AND METHODS

In this case study, local knowledge of drinking water quality and its effect were investigated through multiple qualitative and quantitative research methods and data sources following approaches taken in previous studies (please see, for example, Gleitsmann et al., 2007; Halvorson, 2004; Westaway and Vilgoen, 2000). The qualitative methods employed included: (1) structured interviews with mothers of one child or more; (2) structured household observations; (3) structured interviews with key informants engaged in the health sector, including clinicians, pharmacist and general health officials; (4) a review of governmental and non-governmental statistics and public health documents; and (5) a spatial assessment of water sources, water collection sites, and women's daily water and environmental hygiene-related activities. The quantitative water quality methods included the collection and processing of drinking water samples. The combination of these methods was employed for three reasons. First, this approach allowed for multiple interactions at local household levels between researchers and residents through an informative interviewing component and behavioral observations. Second, these techniques were aimed at capturing the mico-level experience and knowledge of mothers that would have been difficult to elucidate using standard large-scale survey methods. And third, the qualitative data drawn from interviews with mothers helped to inform the process of testing for microbiological contamination of household drinking water sources by providing insights into women's perceptions of sources of contamination and perceived differences between ‘clean’ versus ‘dirty’ or ‘safe’ versus ‘unsafe’ qualities of drinking water (Figure 3). These methods were chosen to provide vital baseline information to help guide water supply interventions and adjustments to hygiene and sanitation education, with the intent of supporting efforts to reduce diarrheal diseases in rural villages.

The goal of the interviews was to learn about mother’s perceptions of drinking water contamination, causes of diarrheal diseases, and effects of the seasonal Niger River fluctuations. Interview respondents were selected based on the criteria that each individual was a mother of at least one living child and expressed a willingness to participate in a study which included household visits and the collection of 100mL of drinking water from the household water supply. There was only one refusal to participate in the survey. The primary instrument for data collection was an interview questionnaire administered orally in the local language (Figure 4). Each interview took between 30-60 minutes and contained 37 questions that were in both closed and open-ended format. Three to five interviews and household visits were conducted each day. The four languages spoken in the study area were Bozo, Fulani, Bambara and Songhoi. In each village as many as three different languages were spoken. The interviews were translated with the assistance of Sidy Ba, an engineer and native Fulani speaker who also speaks Bozo, Bambara and Songhoi languages and speaks English as a fourth language. The questionnaire addressed five areas: (1) general household information; (2) domestic water management; (3) water quality perceptions and diarrheal disease knowledge; (4) perceptions and knowledge of changes in water quality with seasonal changes; and (5) and hygiene and sanitation practices. The basic order of questions was kept constant, although additional questions were raised when it was appropriate and additional probing was added to questions that were answered in a way that implied the respondent might have misunderstood the question. Questions were designed and presented in a way that would not lead the study participants to specific conclusions.

The study consisted of 60 interviews of women representing a range of socio-economic and ethno-linguistic backgrounds. In Dangueri-Maliki every woman that met the aforementioned criteria was interviewed for a total of twenty-one interviews. In the other three villages included in this study, thirteen interviews were conducted in Bargon-Daga, eleven were conducted in Kobaka, and fifteen interviews were conducted in Danuere-Bila. Women made up the target group given their culturally defined roles as primary child care providers and environmental health workers at household and community levels. Systematic research from developing areas, including in West Africa and Mali, indicates that women in particular are socially and culturally situated as the household-scale managers of a range of activities pertaining to domestic water supplies, family hygiene, sanitation, and the care of children suffering from diarrhea and dysentery (Ellis et al., 2007; Adams et al., 2002; Mosley and Chen, 1984). Literature also suggests that women in developing countries often hold the key to reducing childhood diarrheal diseases because of their vital roles as water collectors, food preparers, household sanitarians, and hygiene managers of young children (Halvorson, 2004; Wijk-Sijbesma, 1998; Elmendorf and Isely, 1982). As such, women have the potential to break the cycle of oral-fecal contamination through change in behavior and attitudes towards disease. Since decisions involving water use are the responsibility of women in Mali, women's knowledge about water quality and its effect on their health was of primary concern in this study.

Interviews were conducted in the respondent's house or in her courtyard. During household visits, structured spot observations were employed to observe the spatial layout of the household, the current health status of household members, water storage and water retrieval methods, how water was handled after it is drawn from the well, who was drawing the water out, where the latrine was located in relation to drinking water and food preparation, and hand-washing practices. For each respondent's household a water sample from her family's water jar was collected. These water jars are the most commonly used water storage container and are referred to as *loonde* (Fulani), *figne* (Bambara), or *kusu* (Songhoi). Water quality testing provided the opportunity to both test drinking water for microbial contaminations and to observe how water was drawn from water jars. A total of 60 water samples were collected and tested for coliform bacteria and *Escherichia coli*. For each set of samples we also ran positive (Niger River water) and negative (bottled water) controls. We also collected samples from the Kobaka well and Bargon-Daga well. Water samples were collected in 100mL plastic bottles. The method employed was Coliert®[iv], which tests for presence/absence of coliforms and *E.coli*[v]. Owing to the limited access of electricity, a major challenge was the incubation of the water samples to ensure adequate processing while in the field. As such, the samples – including the positive and negative controls - were physically taped to the abdomen of the author to incubate at body temperature (37.0 °C) for a 24 hour time period Upwards of seven water samples per day were incubated using this low-tech yet highly effective technique.

RESULTS AND DISCUSSION

As mentioned previously, the main aim of this study was to assess patterns in mother's management of water, sanitation, hygiene and diarrheal diseases in relation to seasonal Niger River fluctuations, including the identification of factors that may motivate or hinder salubrious lifestyles and behaviors. In the following paragraphs, the data and key findings from the study are discussed.

Domestic water use and behavior in relation to seasonal fluctuation

Seasonal fluctuations of the Niger River require that people reliant on the Niger River also have to adapt to seasonal changes in their environment wrought by the river (Table 3). According to the study participants, the river begins to rise in late May and early June which causes the water to increase in turbidity and to decrease in quality. As the seasonal rain occurs it causes runoff which carries with it trash and sewage from the surrounding areas and from as far away as Bamako. Study participants indicated that the rainfall facilitates the contamination of water sources as it passes over the ground that is covered in human and animal fecal matter (Figure 5). The water level begins to overflow the banks of the river and every few years floods to bankful width. From late June until the end of the flood stage (around October and November), the water reaches the edge of villages and some villages become islands surrounded by river water and wetlands (e.g., in Dangeure-Maliki, Kobaka, and Dangerui-Bela) (Figure 6-Figure 9). Villagers must use boats to transport goods, to travel across the river, and to reach neighboring communities for school, markets, and social events. The only clinics and hospital in the area are on the east side (Mopti side) of the river. Significantly, villages have greater mobility during this season; boat rides replace walking long distances to the river's edge and make it quicker and easier to access amenities and clinics. As the water table rises, household members are no longer able to use their pit latrines because they become submerged by the high water table, and fecal matter pours out on to the landscape, further contaminating water sources (Figure 10). The edge of the river becomes the primary defecation site, thereby adding to oral-fecal contamination. As the river begins to recede in late November, villagers must walk further to the river's edge and then use a boat to cross the river. Access to other villages becomes increasingly limited during the dry season because the only mode of transportation during that time is walking. People living in Danguere-Bila and Dangueri-Maliki also have limited access to the well in Kobaka during the dry season (Figure 11). Residents in these villages without a well can travel by boat during the wet season to Kobaka to collect well water. If these villagers would like well water during the dry season, they must walk several kilometers to the well in Kobaka and then carry the water back themselves. As the rains cease, the river recedes, the water clarity increases, and turbidity decreases.

During the interviews women reported using ‘black water’ from December and January; this type of water refers to when water has become clear with a lack of suspended material and dark due to the depth of the river. The appearance is described as being dark or black because of the clarity to the bottom of the river. However, after the season of ‘black water’ from February to May, water evaporates rapidly leaving behind what villagers describe as ‘brown water.’ At this time there is little water left in the river channel and the river become braided with many shallow channels. Water left in the main channel continually evaporates, leaving behind highly concentrated contaminated water and heavy sediment load. Women reported attempting to collect water from the deepest points in the stream and walking far out into the river to fetch water. Hygiene decreases during this time with the lack of perceived ‘clean’ water available; however, pit toilets are used as the water table drops.

As mentioned before, several studies have emphasized the correlation between the prevalence of diarrheal diseases and geographic variables such as climate (Anyamba et al., 2006; Lipp et al., 2002; Lawoyin et al., 1999) and especially rainfall (Findley et al., 2005). The local clinics in our study area reported that the height of diarrheal disease occurrence in the Mopti area is June and July, which is the beginning of the rainy season (Table 4). This observation suggests that drinking water is contaminated from overland flow which carries fecal matter into water resources.

Water quality and recontamination

Recontamination of drinking water following collection was observed to be a prevailing issue in the study villages (Table 5). The World Health Organization's (WHO) drinking water standard states that 100mL sample cannot contain any detectable amounts of *E. coli*. The Kobaka well tested negative for the presence of *E.coli*. However, ten of the eleven drinking water samples from this community tested positive for the presence of *E.coli.* The situation here is a typical recontamination issue; the water source is relatively uncontaminated, but unhygienic water handling leads to contamination. The Bargon-Daga well tested positive for the presence of *E.coli.* Each of the respondent's household drinking water sources in Bargon-Daga also tested positive for the presence of *E.coli*. The drinking water samples taken from Danguere-Bila all test positive for the presence of *E.coli.* In Danueri-Maliki twenty families had drinking water that tested positive for *E.coli.*

More than twenty viral, bacterial, and parasitic enteropathogens are presently associated with acute diarrhea. Among the most common are Rotavirus and diarrhea pagenic *E. coli* pathogens which are responsible for acute diarrhea episodes in children (O'Ryan et al., 2005). In testing water quality in this study, fifty-nine (97 %) of respondents' drinking water tested positive for *E.coli*. When asked if their typical drinking water could cause diarrhea, an overwhelming forty-eight of the respondents (80%) said no, six (10%) responded yes, five (8%) did not know and one (2%) responded that 'only God knows.' These data suggest that women are not associating diarrhea with their drinking water and perceive their water to be safe to drink, despite the evidence that their water is contaminated with fecal matter (Figure

12). Further, through additional probing, when asked how they could tell when their drinking water was safe to drink, the majority of the respondents indicated that if the "water is clear, it is clean." The women who participated in this study were not aware of the word 'germ' and were not aware of unseen causes of diarrheal diseases.

Perceptions and knowledge of diarrheal diseases

A low level of maternal education is frequently identified as a major factor influencing high diarrhea occurrences in households (Balk et al., 2003; Agha, 2000; McMurray, 1997). According to public health statistics for rural Mali, diarrheal diseases account for one of the greatest causes of deaths in for children under 5 years old (DHS 2006). Diarrhea was not reported as a child health issue by twenty-nine (48%) of respondents, despite the majority of the respondents using unimproved water resources. On the contrary, the Mopti clinicians reported that diarrhea was an extremely serious health problem in the area along with malaria. Of the total women interviewed, a little over half (60%) had lost one or more children before the age of five. Half (50%) of the respondents reported losing two to five children before the age of five. Three mothers reported the death of as many as six to seven of their children before the age of five. In light of these women's experiences with child death, there is a tremendous need in this area to investigate child mortality and to establish baseline data on the causes of infant and child death. While it is beyond the scope of this paper to assess the causality of death of respondents' children, it is evident from observations and field data, especially the wide-scale presence of E.coli in Niger River water samples, that children are vulnerable to waterborne disease.

In general, the interview data suggests that there seems to be a misunderstanding about the severity of diarrhea and the identification of severity among children. An adult can live with diarrheal symptoms because of well established immune systems and nutritional reserves; on the other hand, a child is likely to suffer from dehydration and malnutrition. Since adults can live though the symptoms they may not see the urgency of providing clean water, food and seek medical help for their children with the same symptoms. From a study in the Republic of Guinea-Bissau, Sodemann et al. (1996) found that runny stools (i.e., stool type) were generally not perceived by mothers as a type of diarrhea unless it contained blood and was associated with pain. Mothers in this example were not recognizing non-bloody diarrhea as a cause of death or a critical health issue for young children; therefore, their response and actions to seek health care were delayed. Another study from northern Africa found in Somalia that traditional healers had treated children with diarrhea by removing their lower cuspid teeth (Graham, 2000). Several children from the same study had a hot nail pressed into their gums in the area of the lower cuspids as a treatment of an episode of gastroenteritis. In Zimbabwe researchers found that local knowledge of disease causation could be lumped into two broad classes: 'physical' causes and 'social and spiritual' causes of diseases. They concluded that "health care activity should build on local perceptions about illness and its control" (de Zoysa et al., 1984, page 727). Bilenk (1999), in his study in Israel, reported that approximately half of the mothers reported the cessation of breastfeeding as a treatment to diarrhea. These are just few examples of cultural practices and traditional knowledge that affects health seeking behavior and influence perceptions of the causal mechanisms of childhood diarrhea.

Included in the interview was the question of how people get diarrhea (Table 6). The majority of respondents gave at least several causes of diarrhea, sixteen (26%) of which mentioned dirty water. Only two (3%) mentioned dirty hands and the highest reported response given by eighteen (30%) study participants was that they do not know the cause of diarrhea. Three mentioned (5%) that ‘only God knows’ or has the power to decide who suffers illness. Without probing, nine respondents (15%) mentioned teething as a cause of diarrhea. After respondents answered the question, further probing was aimed at identifying what other factors were perceived as potential causes of diarrheal illnesses. This probing resulted in a much expanded list of possible causes. Teething and super natural force was mentioned and eight (13%) study participants mentioned spicy foods.   An overwhelming fifty (82%) women responded that diarrhea was caused by childhood teething. This same finding has been found elsewhere in West Africa (Bankole et al., 2005; Sarrell et al., 2005; Kauchali et al., 2004; Ene-Obong, et al., 2000; Sodemann et al., 1999; Sodemann et al., 1996;).   However, Johnsen (1996) has stated that there is little evidence that teething is the cause of diarrhea, fever and facial rashes. Sodemann et al. (1996) found that diarrhea was perceived to be caused by teething to delay medical attention. Mothers in our study responded that they believed teething diarrhea to be ‘normal’ and not as dangerous as other types of diarrhea, and therefore they indicated that they delay seeking medical help and disregard oral rehydration solution (ORS). Previous studies have emphasized the importance of health education programs that stress the recognition of the early signs of dehydration and discourage 'teething' as an explanation of diarrhea (Sodemann et al., 1996). Based on the observations made during this study, teething may not be a direct cause of diarrhea, but it may be an indirect cause of diarrhea. During interviews, children of teething age were observed crawling on hands and knees along dirt courtyards where humans and animals had defecated. At this age, children repetitively put their hands in their mouth, initiating the oral-fecal cycle which in turn causes diarrhea. This cycle of oral-fecal contamination was not recognized by forty-five (75%) of respondents. Only nine (15%) of the respondents identified feces as a cause of diarrhea. Further 44% of the respondents did not know how to keep their children from getting diarrhea which indicated that these mothers lack the education and knowledge of hygiene and the related causes of diarrheal diseases.

Treatment of the disease is in large part dictated by the mothers' understanding of the severity of the illness and evaluation of the costs associated with treatment. The majority of respondents mentioned the use of clinics and several mentioned buying prescribed drugs from the clinic. A difficult component is that women mentioned that they do not know at what severity it is necessary to take their child to the clinic and at what cost, both in time and monetarily. One woman reported that her child had diarrhea for 3 years before she took the child to the clinic, stating that only once it became life threatening. The first cost in treating diarrhea is the time spent away from farming and fishing as well as care giving to the rest of the family. The second cost is if the family does not own a boat. A ride across the Niger can be a relatively expensive ordeal for women who may not have access to cash. The clinics are, however, free of charge for basic health care. According to the local clinic personnel in Mopti, free checkups for children with sicknesses, which includes free ORS and IV's if the child is severely dehydrated, is provided. The clinic reported that the biggest concerns in the area are malaria, respiratory infections, chronic diarrhea diseases and consequently a large portion of dehydrated and malnutrition children. Only 16% of mothers indicated that they went to the clinic if the diarrhea persisted after trying other methods, such as medicinal plants and medications bought from street peddlers. The most common drugs mentioned were Gandia (Sulfadimidine) and Toopie (Amoxicillian); one woman even mentioned the use of Chloroquine to treat diarrhea. These drugs are both anti-parasitic and anti-bacteria and health workers at the clinics discourage the use of these drugs because they are not effective. Several

(15%) of the women mentioned the use of ORS and usually in conjunction with other treatments.

Sanitation and hygiene practices: Education uptake and adoption

When mothers were asked about when they start giving their children drinking water, forty-two (70%) responded either at birth or within the first few days. Fourteen (23%) respondents said from 3-4 months, three (5%) said after 6 months and several mothers could not recall the information. Several women mention that the radio advertisements recommend exclusive breastfeeding the first 3months, but they responded that they did not follow this suggestion. One women stated, "I've heard it is better to wait 6 months before giving a baby water, but it is customary to give water at birth, so that is what I do." Several women confirmed the widespread practice of giving babies water at birth or within a few days. One woman responded," We give our babies water at birth by dipping our fingers in water and then putting it into their mouths, this is our custom". With the poor hygiene of these women (lack of hand-washing), coupled with fecal contaminated water, infants are highly exposed to enteric pathogens leading to diarrheal illnesses. Several mothers reported that the television (there is not electricity in the villages on the west side of the Niger river and television would have been watched while in Mopti) advocated exclusive breastfeeding for the first six months, but again respondents reported that they only breastfeed the first three months. It does not appear that the health advertisement in the area is effective at changing behavior patterns.

Respondents were asked about whether or not they observed an increase in diarrhea frequency after giving the child water. Seventy-five percent mentioned they did not think diarrhea was an issue, while six (10%) women responded, 'yes', that they did notice diarrhea became a problem. One woman responded "Yes, because babies always have diarrhea." As mentioned before, mothers may not be calling diarrhea what we would define diarrhea. There is potentially a misunderstanding of what is normal in a healthy setting for childhood diarrheal frequency. Several women said that their children get diarrhea after they start them on water at birth and said "…we give the water so they clean out the bad things their stomach…the diarrhea is normal." Another woman put it this way:

> When the baby is born the stomach is runny for 40 days and then the feces start to harden then they know the babies' stomach is clean; when the mother eats the food it goes to the baby in the womb and the baby needs to clean this out when it's born.

Another woman mentioned that water cleans out the stomach of the baby: "The local belief is that at birth there is material in the baby's stomach that if you give them water they get a runny stool which is not a bad thing, it is just part of a cleaning out process." Again the severity of the runny stool may not be addressed, which can lead to childhood dehydration and a loss of nutrients, if not properly addressed as an issue.

The clinic also publishes radio advertisements concerning health and hygiene. In a study by Cairncross and Shordt (2004) from Kerala India found that hygiene promotion programmes implemented at the community level are more successful than at a large scale which tries to incorporate too many cultures. In the case of these field sites, mass communication campaigns via radio seemed ineffective in encouraging behavioral changes. A site-by-site health program could be more adaptable to the cultural practices of the residents in these villages. For instance in the Mopti areas, a health program would need to address the issues of mothers preference to give their babies water at birth and could incorporate a message about the importance of using clean or purified water for this ritual and administered by clean hands.

SYNTHESIS OF MAJOR FINDINGS

A synthesis of the aforementioned results leads to the following four major points:

(1) The seasonal flux of the Niger River Inland Delta has a profound influence on water management, hygiene, sanitation conditions, and accessibility to health clinics. Dramatic seasonal fluctuations of the Niger River require that women adapt to seasonal changes in their surrounding environment and deal with changing water quality and quantity. For those living on the east side of the Niger River, Mopti, they gain accessibility to clinics and amenities with inundation periods and are isolated during the dry season. In Mali, diarrhea is a seasonally driven and accentuated by climate variability (Findley et al., 2005). By knowing cultural practices and local climate variability, health programs can more effectively teach about improved handling methods of water in advance of disease prone seasons.

(2) Recontamination of drinking water seems to be a prevailing issue in the Mopti Region. Some villages have access to clean water but contamination seems to take place during transport and storage within the household. Despite the fact that nearly all of the household drinking water samples tested positive for *E. coli*, respondents overwhelming did not believe their drinking water could cause diarrheal diseases. This finding suggests that women are not associating diarrhea with their drinking water.

(3) Women most commonly responded that they did not know how to prevent diarrhea nor they did not know the cause of diarrhea. We observed that teething is a probable indirect cause of diarrhea among small children; children at the teething age are more susceptible to oral-fecal contamination since they are crawling in areas with fecal matter and persistently putting hands and objects in their mouth. Mothers may not be recognizing the severity of diarrhea as a cause of death or an serious health issue in young children, therefore delaying health seeking and

their response to treatment. Mothers reported diarrhea as a low concern in children, while health workers from Mopti clinics reported diarrhea as a serious problem in both rural and more densely settled areas around Mopti. There seems to be a misunderstanding about the severity of diarrhea, especially if it occurs in children who are teething, and in these cases diarrhea is perceived as normal.

(4) Due to cultural practices women in our study area feed their babies unhygienic water at birth by hand, which is a likely cause of diarrhea. Women mentioned local radio advertisements for exclusive breastfeeding and refraining from giving babies water at birth; however, respondents did not take heed to these health warnings. It has been well documented that mere knowledge of diarrhea transmission is simply not enough to encourage mothers to change habits and cultural traditions, especially if the knowledge is in conflict with daily routines and cultural habits (Halvorson, 2004; Westaway and Viljoen, 2000).

RECOMMENDATIONS AND CONCLUSION

Simply identifying these findings and the major areas of concern in regards to securing child survival and reducing waterborne disease is only part of the entire process of reducing childhood diarrhea in resource poor areas such as the Mopti region of Mali, West Africa. Based on the results of this field-based study, four steps stand out as being essential to achieving any progress in reducing waterborne disease. First, it is key to gain an understanding of local water and health-related beliefs, customs and daily life habits as well as understanding complex seasonal variability and create a health program that is grounded in the realities of the grassroots level. A second step is to provide an opportunity for education uptake, possibly in the forms of health, hygiene and sanitation classes in women's homes or at the neighborhood scale. This step should include research into how local communities would like to receive science-based water quality and health information, such as through focus group discussions lead by health professionals and/or possibly as simple radio educational commercials in local dialects. Educational materials and the types of dissemination should be based on the community's primary concerns and designed through multiple interactions with local residents. Third, there needs to be an ongoing assessment of the adoption of new knowledge and the acceptance of small changes that can reduce children's vulnerability, and in turn, improve women's situations. This step also involves seeking an understanding of both the constraints to learning as well as the opportunities for new ways of sustaining learning about health and water hygiene. And finally, only after these first three steps have been carried out is it appropriate to implement a technical intervention, say for example, a water pump or filtration device, aimed at reducing waterborne diseases (Ba, 2008). There are decades of studies to prove that without these steps, funding, time and energy can be wasted through short-sighted attempts to reduce preventable disease. Despite the trillions of dollars spent on research and development projects, mortality rates by waterborne pathogens have risen with population growth. In fact, Easterly (2006) claims that research has shown very poor results given the expenditure of such a great amount of funds. He blames it on "Planners" who seek to impose solutions from the top down rather than "Searchers" who adapt to real life and cultural circumstances from the bottom up. The mind set of "Planners" is a reason why water interventions designed by outsiders have a record of failure with few results pertaining to the reduction in the incidence of waterborne diseases (Calderisi, 2007; Easterly, 2006).

This study assessed linkages between water and health, environmental interactions, cultural practices, and behaviors as part of a larger ongoing effort to provide a baseline data set for planning water hygiene and health promotion programs in the Mopti area. The effectiveness of locally-informed education programs has the potential for clarifying misconceptions, improving practical knowledge and instigating behavioral changes which in turn may reduce diarrhea-related mortality along a more sustainable long term platform than what has been undertaken to date in the Niger River Basin of Mali, West Africa. The findings on cultural practices, beliefs, knowledge and local river hydrological climate variability suggest a need for greater sensitivity to geographic context when designing water and environmental hygiene education. Further, and of great importance, is supporting women living in the Mopti area, learning from them, and working with them in a collaborative and experiential manner to develop practical solutions to water and health challenges.

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[i] Diarrhea is a symptom of infection caused by a host of bacterial, viral and parasitic organisms primarily spread by contaminated water, especially via human and animal feces. Diarrhea can also be spread from person to person and is aggravated by poor hygiene and sanitation.

[ii] This research was part of a large project initiated by Sidy Ba who earned his Masters of Engineering from Montana State University, Bozeman in 2008. He is a native Malian and attended primary school near Mopti, Mali. His master's research focused on designing a water filtration system using slow sand filtration. His plan is to implement the filtration system in an area near Mopti. He suggested the four villages we conducted our surveys in so that he could use the information to make decisions on the design and implementation of the water filtration system. As recommended by this paper, there are at least four steps to successfully reducing diarrheal diseases; Sidy Ba plans to follow the first three steps before the implementation phase of the slow sand filtration system.

[iii] Educated estimates of the number of households in each village was made because there is no census data for rural villages around Mopti.

[iv] (IDEXX Laboratories Coliert Westbrook, Maine)

[v] The test required the collection of 100ml of sample water in a sterilized container. Then the Coliert® fluorescence indicator powder was added. The sample was then incubated at 36ºC for 24 hours. Samples were temperature regulated by being incubated and regularly checked with a sterile thermometer. After a 24 hour period, a control was used to check for the presence or absence of coliforms. Then using a black light, the samples were checked for fluorescence which indicates the presence *E.coli*. The presence of coliform bacteria and *E.coli* in aquatic environments indicates that the water has been contaminated with the fecal material from humans and animals. The World Health Organization (WHO) drinking water standard allows for coliform organisms in up to 5% of samples taken over any 12-month period, provided *E.coli* is not present. The WHO has set the standard for potable water for zero indication of *E.coli* in drinking water to meet international standards. For each day that we collected sample drinking water, we also ran a positive and negative control. For a positive control Niger River water was used since it was obviously highly contaminated with fecal matter, so much that it was visibly present. As a negative control we used purified bottled water.

[vi] There is a lag time of several years for updated health information. The most recent publication from the Malian government was 2008 which was the DSM, 2006.

APPENDEX A – TABLES 1- 6

Table 1. Social and health development indicators for Mali.

Total Population (000)	12,337
Population living Urban	26.8%
Population living Rural	73.2%
Births (000)	579
Under-Five Mortality (per 100 live births)	217
Infant mortality rate (per 1000 live births)	119
Neonatal mortality rate (per 1000 live births)	55
Total under-five deaths (000)	126
% of children under 5 years with decline in growth or mild malnutrition, rural	20
% of children under 5 years with acute malnutrition or decay in growth in rural areas is also 20%, rural	20
Population living below poverty line (US$1.25 per day)	51%
Annual per capital income	US$1,058
% of population with no formal education, urban	55.1
% of population with no formal education, rural	81.5
% of adult illiteracy rate for those 15 years and older. rural	77.1

Data source: DSM, 2006; UNCEF, 2007[vi]

Table 2. Water and Sanitation for Mali 2006

	Urban	Rural	National
% of population using improved drinking-water sources	79	46	56
% of population using improved sanitation facilities	59	39	45

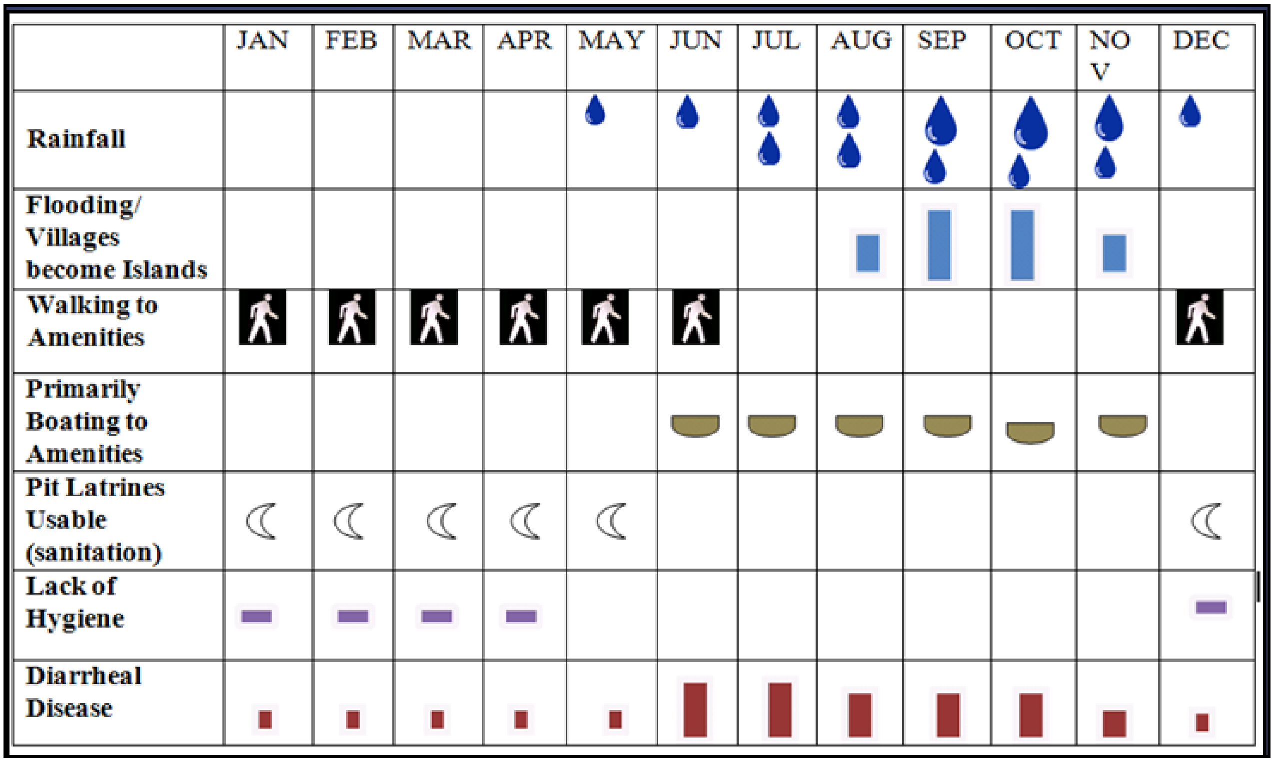
Data source: UNECF, 2006

Table 3. Seasonal adoption to seasonal changes for each village

Village Name	Wet Season June-March	Transition Wet to Dry	Dry Season March-June	Transition Dry to Wet
Kobaka	Boat (Cost): 200CFA francs Distance: 4km	Boat/walk/cart (cost): 100-150CFA francs Distance: 4km	Cark/Walk (cost): 0-75CFA francs Distance:5 km	Boat/cart/walk (cost): 75-150CFA francs Distance: 4km
Danguare-Maliki	Boat/cart/walk (Cost): 150 CFA francs Distance: 3km	Boat/cart/walk(cost): 0-100 CFA francs Distance: 3km	Cart/walk (cost): 0-100CFA francs Distance: 3km	Boat/cart/walk(cost): 0-100 CFA francs Distance: 3km
Danguere-Bila	Boat(Cost): 100CFA francs Distance: 1.5km	Boat/walk (cost): 0-50 CFA francs Distance: 1.5km	walk(cost): 0 CFA francs Distance: 1.5km	Boat/ walk (cost):0 -50CFA francs Distance: 1.5km
Baron Daga	Boat/cart/walk(cost): 0-100CFA francs Distance: 2.5km	Boat/cart/walk(cost): 0-50CFA francs Distance: 2.5km	Walk/cart: 0-50CFA francs Distance: 2.5km	Boat/cart/walk(cost): 0-50CFA francs Distance: 2.5km

(Source: Ashley Williams, 2009).

Table 4. Graphical representation of seasonal variability and water use on the Niger River.



(Source: Ashley Williams, 2009).

Table 5. Water contamination of residence in Mali

Village Name	Drinking water source	Presence of *E.coli* at source	% of respondents drinking water at home **containing *E.coli***
Kobaka	Cement encased drilled well	Negative (-)	91%
Danguere-Bila	Niger River	Positive (+)	100%
Danueri-Maliki	Niger River	Positive (+)	100%
Bargon-Daga	Brick hand dug well (no cover)	Positive (+)	100%

(Source: Ashley Williams, 2009).

Table 6. Perceived causes of diarrheal diseases for children under 5 years old (N=60)

Causes	Frequency	% Mentioning
Do not Know	18	30
Contaminated (dirty) water	16	26
Contaminated (dirty) food	11	18
Malaria	10	16
Teething	9	15
Food related (milk, poorly spiced food, unhealthy food and uncooked meat)	5	8
Only God knows and decides	3	5
Flies	2	3
Unwashed hands	2	3
Visitors	1	2
When mother have diarrhea and breast feeding	1	2
Children playing in the mud	1	2

(Source: Ashley Williams, 2009).

APPENDEX B – FIGURES 1 – 12

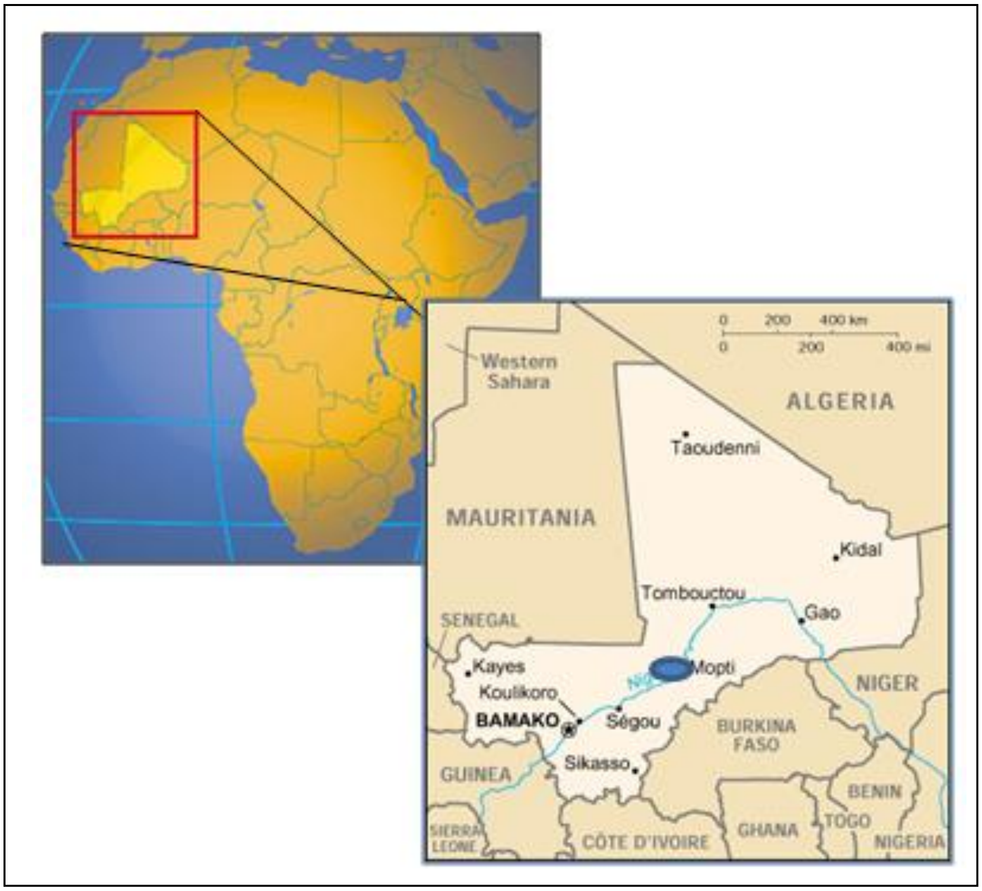


Figure 1. Location map of Mopti, Mali. (Source: Ashley Williams)

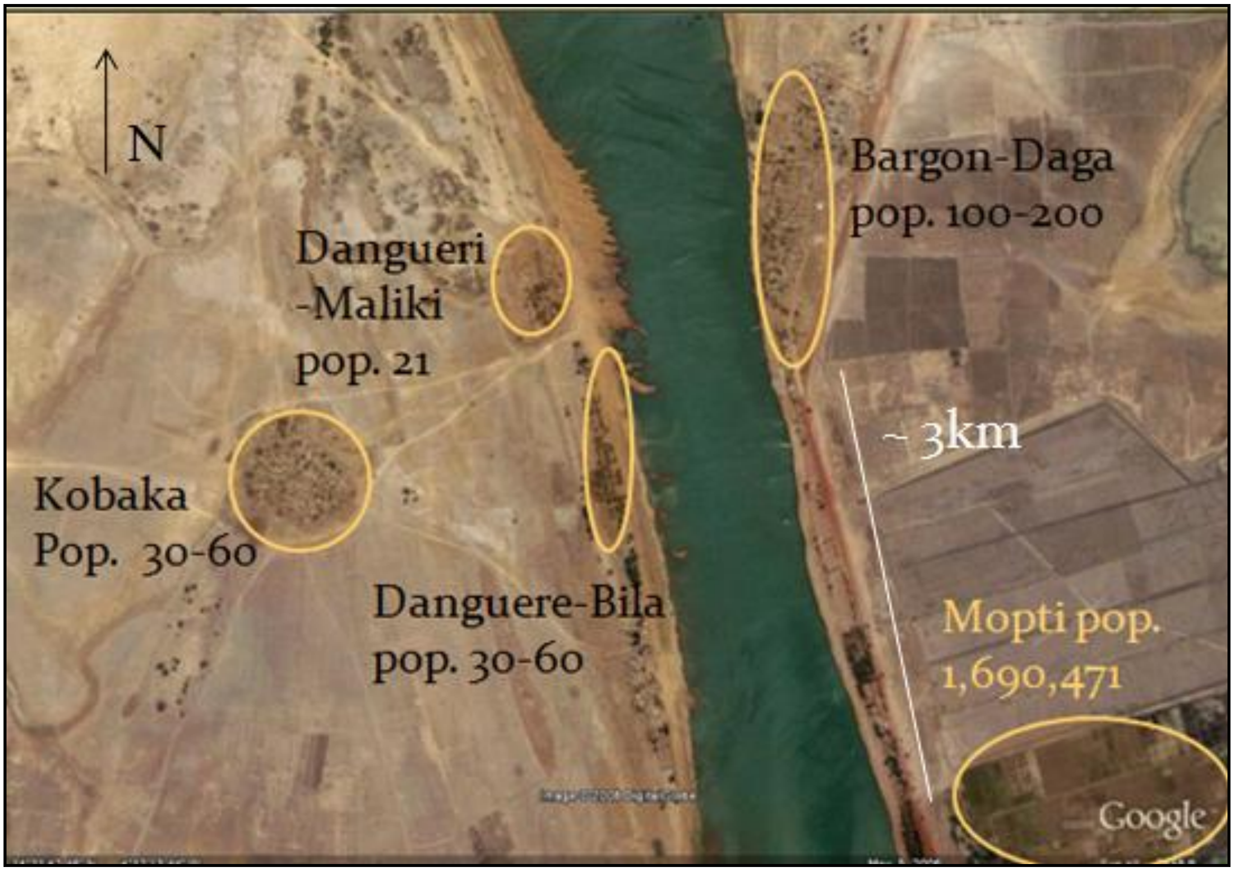


Figure 2. Location map of study villages (Source: Ashley Williams, 2009; GoogleEarth, 2009).

Figure 3. We interviewed 60 women from four villages. During the interview we asked women about their drinking water filtration techniques (shown in photo). Women from our study area collect drinking water from the Niger River and then strain water though plastic mesh, which did not appear to filter much except large debris. (Source: Ashley Williams, September 2009).

Figure 4. Women living in Kobaka belong to the Fulani tribe. Fulani women and children have deep purple tattoos near the eyes and around the mouth to symbolize which tribe they are from (Source: Ashley Williams, 2009).

Figure 5. This is a typical example of fecal matter from pit toilets draining into the Niger River. Women collect drinking water within several yards from this fecal runoff zone (Source: Ashley Williams, 2009).

Figure 6. This is a typical looking village along the Niger River near Mopti during the rainy season. The water levels are right up against the village allowing villagers to become more mobile. Boat rides replace long walks to the water's edge (Source: Ashley Williams, 2009).

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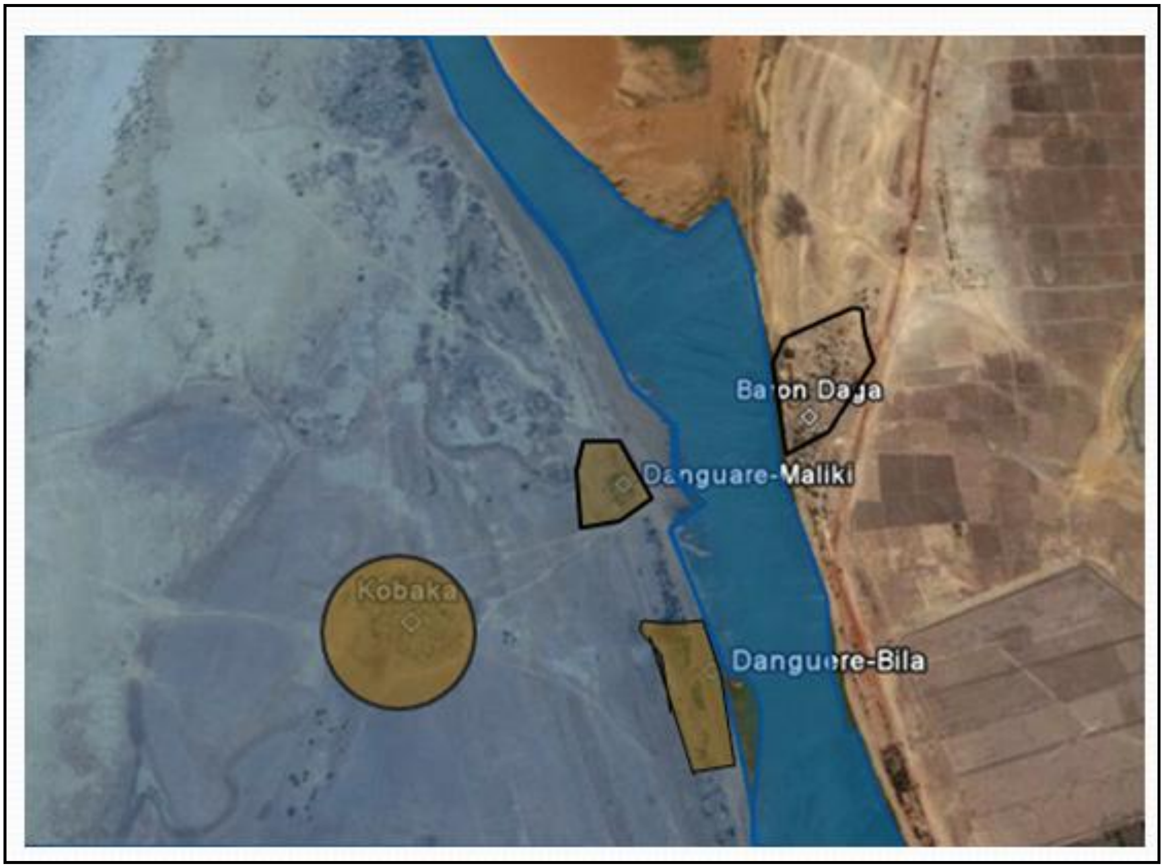

Figure 7. This is a visual sketch of inundation in the Inland Delta during high water level (Source: Ashley Williams, 2009).

Figure 8. During the rainy season village banks are eroded away by the high water levels. This photo was taken from the Niger River looking at the eroding banks of Dangueri Maliki. Erosion barriers are put into place (wood fence as seen in photo). However, these efforts appear to do little in the way of stopping village erosion (Source: Ashley Williams, 2009).


Figure 9. The Niger River near Mopti during the rainy season looks like a series of connected wetlands off the main river (Source: Ashley Williams, 2009).

Figure 10. This is a photo of the village of Danguere Bila. Feces and other forms of contamination were observed in this location along with flooded pit toilets. Women collect drinking water from this shallow contaminated area and then use minimal filtering techniques before drinking (Source: Ashley Williams, 2009).

Figure 11. Kobaka was the only village in the study site with a cement encased pump well. This was the only drinking water source that tested negative for *E.coli*. The well is partially submerged during the Niger River inundation period (Source: Ashley Williams, 2009).

Figure 12. Villages in the study area struggle with hygiene and sanitation issues, especially with fecal matter getting into the drinking water. This photo is from Bargon Daga, the village on the east side of the Niger and closest to the city of Mopti. Water buckets are sitting in animal feces. These buckets are then used to dip into the well (right side of photo), adding fecal matter to their drinking water source. Homes are directly adjacent to the animal corrals and pens, allowing for fecal matter to be easily carried by hands and feet into the house by children and adults (Source: Ashley Williams, 2009).

APPENDEX C - QUESTIONNAIRE

Part I: Respondent and Household Information

1. How old are you?
2. What is your occupation?
3. How many children do you have?
4. How many years did you attend school?
5. Does your household own any animals? What kind and how many?
6. Where are the animal kept?

Part II: Domestic Water Management

7. Where does your family's drinking water come from? Prob: Does everyone drink from one source?
8. What do you like about your water? (taste, smell, color, temperature…etc.)
9. Does the quality change with the season? Winter vs. summer drinking water sources?
10. What time of day do you collect your water?
11. Who collects your drinking water?
12. What do you use to collect your water?
13. How do you store your water?
14. Do you doing anything to your water before you drink it? (boil, pasteurize, chlorinate, other…etc.)
15. What in your opinion is dirty drinking water?
16. Is your drinking water safe to drink?

Part III: Diarrheal Disease Knowledge and Perceptions

17. How do you believe the people in your village get diarrhea? Probe: Can your normal drinking water cause diarrhea?
18. Do you know how you can avoid/prevent yourself or your family members from getting diarrhea? It means measures to be taken before becoming ill?
19. What is the frequency of diarrhea for your children? (ask to explain the types)
20. Is there a season that your kids get sicker (summer vs. winter or rainy vs. dry)?
21. Can diarrhea be spread through children's feces?
22. Do you believe that very young babies (before they can walk) can spread diarrhea through feces?
23. Do you believe in supernatural forces are the cause of childhood illness?
24. What do you do to treat diarrhea?
25. What natural remedies and treatments do you administer to you children?
26. Do you use any plants or foods as remedies?
27. Have you heard of ORS? Could you explain how you've used it?
28. Do you have a medical healer in this village or a village near by that works with diarrhea issues?
29. What does he/she recommend for diarrhea?
30. Have you ever taken any children of yours to the clinic for diarrhea?
31. What have they recommended or prescribed? Do you administer medication to the child?

Part IV: Change in Water Quality and Use beyond Drinking

32. What are the causes of water contamination within your community?

33. Have you noticed a change in water quality? Probe: How has the Niger River changed or has it not changed?
34. Have you noticed a change in the amount of water available or the level of the Niger River?
35. What types of land changes have you seen in and around your village? Is there irrigated agriculture in the area and has this affected the population?
36. Do you use water for any ceremonies?
37. What does the water symbolize to you?
38. Do you use water as part of any religious practices?
39. What does the Muslim faith say about drinking water? Or other uses of water?
40. Do you tell any stories about water to children or have you heard any stories told to you about water and health or danger?

Part V: Hygiene and Sanitation

41. When are the most important times to wash hands?
42. Why is it important to wash your hands?
43. Can apparently clean hands (show hands- no black or dirt) spread diarrhea? Prob: Could diarrhea spread from hands to people? How could this happen?
44. What is a germ?
45. Have you ever had any hygiene or sanitation classes or educational opportunities? (any Peace Corps Volunteers or other organizations visit your community to teach)
46. Where do you go to market? How often? Do they sell soap? Do you ever buy the soap for your house? Who pays for that?
47. Where does your family go to the bathroom?

48. Where is this defecation site located in relation to the house? (Far/Near)

49. Where do you wash the child's dirty nappies?

APPENDIX D – OBSERVATIONAL GUIDE & CHECKLIST AND WATER QUALITY CHECKLIST

Household Number:

Interview Number:

Date and Time:

General Household and Child Care Environment

1. Space: Layout of physical setting (rooms, kitchen, outdoor space, location of water)
2. Current health status of the household members
3. Where is water stored?
4. How is water being handled? How is water drawn out of storage container?
5. Who draws water out?
6. Is water covered or uncovered?
7. Where is the latrine?
8. Where is food prepared?
9. Where, when and how do family members wash their hands?

Household Number:

Interview Number:

Date and Time:

Source: [Well] [Niger River] [Open Water Source-Pond] [Other]

Source Details: [consider: well casing, open to run off, shaft, depth of shaft, pump type, bucket,

Primary during: [Summer] [Fall] [Winter] [Fall]

Drawing Devise: [Bucket] [Pump] [Other]

Drawing Devise Details:

Parameters:

Coliform Bottle Number:________________

24hr incubation: Coliform [Presence] [Absence] ***E. Coli*****: [Presence] [Absence]**

Tubidity:________NTU pH:____________ Temperature:_________

Nitrite:______________ Nitrate:_________ Conductivity:___________

Arsenic___________