Is Drinking Water in Abidjan, Côte d'Ivoire, Safe for Infant Formula?

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ABSTRACT

Objective: To survey knowledge, attitudes, and practices regarding water use and infant feeding in the Koumassi District of Abidjan, Côte d'Ivoire, and to evaluate the microbiologic quality of source and stored drinking water.
Design: Random-cluster household survey.
Methods: We randomly selected 20 clusters, each comprising six households with at least 1 child aged less than or equal to 3 years. In each household, we administered a questionnaire and collected source and stored drinking water samples and tested these for chlorine levels and for total coliform and fecal bacteria count (*Escherichia coli*).
Results: Municipal water was used for drinking in 112 (93%) of 120 households, and in 99 (83%), it was stored for later use. By 1 month of age, 97 (90%) of 108 infants given drinking water were given stored water for drinking. In 8 (66%) of 12 households where children were receiving artificial feeding, formula was prepared from municipal water without additional treatment. Stored water had lower levels of free chlorine than source water (median of 0.05 versus 0.2 mg/dl; *p* less than .001), and *E. coli* was detected in 36 (41%) of 87 stored water samples and 1 (1%) of 108 source water samples (*p* less than .001).
Conclusions: In the Koumassi District of Abidjan, where municipal water is widely available and of good quality, drinking water is stored in most households, is often contaminated with *E. coli*, and is given to children at a young age. If replacement feeding is to be more widely used to prevent postnatal transmission of HIV-1, communities using stored water need interventions to make stored water safer.

Key Words: HIV; Diarrhea; Water; Infant formula

In developed countries, HIV transmission from mother-to-child has decreased dramatically by the use of antiretroviral therapy and replacement of breast-feeding with infant formula [1]. In developing countries, short-course zidovudine and nevirapine regimens have recently been proven effective in preventing mother-to-child HIV transmission [2–4]. Nevertheless, because most HIV-1–infected women breast-feed their infants, transmission of HIV through breast milk may still occur despite effective antiretroviral therapy. Up to 16% of children born to HIV-infected mothers acquire HIV-1 through breast milk in Africa [5–8]. Specifically, in West Africa, mothers given short-course maternal zidovudine in late pregnancy had a postnatal HIV transmission risk of 9.4% [9]. Recently, the Joint United Nations Program on HIV/AIDS recommended that HIV-positive mothers be informed of the risks and benefits of breast-feeding and that they be given guidance in considering all options, including substituting formula for breast milk as one means to reduce the risk of mother-to-child HIV transmission [10]. The use of infant formula in developing countries has been associated with higher rates of diarrheal morbidity and mortality, in part, because it may be prepared from contaminated water and because the high nutrient content and low acidity of formula provide a favorable growth medium for bacterial enteric pathogens, especially when held at ambient temperature [11–13]. Infants born to HIV-infected mothers may be at particularly high risk for infection and severe disease from bacterial enteric pathogens [14].

United Nations Children's Fund (UNICEF) and other international organizations are currently providing formula to maternal health clinics for HIV-infected mothers who choose to use infant formula, in addition to antiretroviral drugs, to prevent mother-to-child transmission of HIV [15]. It is important to assess the microbiologic quality of water used to prepare infant formula, especially in areas heavily affected by the HIV epidemic and to consider measures to protect formula and the infants for whom it is prepared from waterborne pathogens. We conducted a study in a community in Abidjan, Côte d'Ivoire, to evaluate the quality of water available to prepare infant formula as well as knowledge, attitudes, and practices regarding water practices and infant feeding.

METHODS

This study was conducted from April to June 1999 in the Koumassi District of Abidjan, which consists mostly of households of lower socioeconomic status. To assess the water quality and practices of women with HIV, we used 20 randomly selected households of women who attended the HIV clinic at the Koumassi mother-child clinic as a starting point for the cluster survey. We moved in a random direction away from the starting point, and we chose every tenth household with a mother or caretaker of a child $\leq$ 3 years old living in the household. If there was no mother or caretaker; no one who spoke French, Dioula, or Baoule; or no child $\leq$ 3 years of age, the team proceeded to the next closest household until they located 1 caretaker eligible for inclusion. We collected information by interviews in French, Dioula, or Baoule on 6 households in each neighborhood cluster for a total of 120 households. In each household, we interviewed the mother or caretaker using a field-tested questionnaire, and we obtained a sample of the stored water given to the youngest child for drinking and a sample of the source water from which it was obtained.

Data were analyzed using Epi-Info 6.1 (version 6.1; Centers for Disease Control and Prevention, Atlanta, GA, U.S.A.) [16]. The protocol was reviewed by the Human Subjects Activity Office of the Centers for Disease Control and Prevention and was judged to be exempt from full Institutional Review Board review because it involved no intervention and was collecting only anonymous nonsensitive information. Verbal informed consent was obtained from each participant.

LABORATORY

Water samples were collected in two 300-ml Whirl-paks (Nasco International, Inc., Ft. Atkinson, WI, U.S.A.), one of which was impregnated with thiosulfate. The sample without thiosulfate was evaluated for total and free chlorine levels with a Hach digital chlorimeter (Loveland, CO, U.S.A.). The samples with thiosulfate were transported in a cooler with ice to the laboratory for evaluation within 6 hours by Colilert (IDEX, Westbrooke, MA, U.S.A.) for total coliform bacteria colony counts and Escherichia coli colony counts. Colilert provides a reliable and efficient means of detecting coliforms and *E. coli* fecal contaminants in water supplies [17,18]. One hundred milliliters of the sample was mixed with the reagent provided, poured in the Colilert tray, and sealed by the Colilert sealer. Colilert trays were placed in a 35°C incubator for 24 hours, after which we determined the most probable number, an estimate of the colony-forming units per 100 ml of water.

RESULTS

We interviewed 120 primary caretakers representing 120 households in nine neighborhoods of Koumassi. Seventy-five (63%) respondents lived in a home with a courtyard shared by 6 to 10 households. Seventy-four (60%) caretakers had received prenatal consultations at the Koumassi mother-child clinic. There were 1 to 3 children $\leq$ 3 years old in each household. The median age of the youngest child was 13 months (range: 1–36 months). The median age of the primary caretakers was 27 years (range: 15–49 years). Forty-nine (41%) caretakers had no formal education. Thirty (25%) families spoke French as the primary language in the household, 20 (17%) spoke Dioula, and 16 (13%) spoke Baoule. The remaining 54 households used local dialects as the primary language spoken in the household.

Water from the municipal system (either obtained by household tap or collected in a storage container from a community tap) was used for drinking water for 112 (93%) households; the remaining households used bottled water. In 49 (44%) of these 112 households, the source for municipal water was a tap inside the house, and in 62 (56%), it was from a community tap. Although no one reported using well water or river water for drinking, these sources were used for washing clothes and dishes in 26 (22%) households. Caretakers spent between 10 and 500 CFA (median of 50 CFA [$0.08]) every month for drinking water, which included fees for a community or household tap. Nineteen (16%) caretakers reported that the tap they used only worked sporadically.

Drinking water was typically collected by a family member, usually the mother, and was stored in 99 (83%) of 120 households. Drinking water was stored, primarily because taps were either located at some distance from the house, were unreliable, or both. The storage container in 76 (63%) households was reportedly closed with a lid; however, we observed that they were often left open or were only loosely closed with a plate or flat object placed on top of a large opening. The storage containers were made of plastic in two thirds of homes and cost between 25 and 7000 CFA (median of 1200 CFA [$2.00]). To remove water from the storage container, 83 (84%) respondents reported dipping a cup in the opening of the storage container, and only 16 (16%) reported pouring water out.

Children were first exposed to drinking water at an early age. Sixty-four (63%) of 102 mothers reported giving their infants local bottled water (Awa, Abidjan, Côte d'Ivoire) during the newborn's first week of life. By 1 month of age, 108 (90%) of 120 infants had been given drinking water, and 97 (90%) of these infants were given stored drinking water. At the time of the interview, the youngest child was drinking stored water in 89 (74%) households. Only 3 (3%) of 97 women who described giving stored water to their youngest child treated this drinking water; all 3 did so by boiling the water. Among children who had been weaned from breast milk, the median weaning age was 18 months (range: 2–36 months).

Virtually all (98%) caretakers believed breast-feeding was best for infants because of nutrition, tradition, and cost. Sixty-three (52%) of 120 mothers expressed concerns about infant formula; some of these concerns included the risk of diarrhea (33%), need for meticulous preparation (21%), and decreased nutritional value (6%). Only 12 (10%) caretakers were formula-feeding their infants at the time of our study. In each of these homes, bottles were most commonly prepared from tap water (66%) or Awa, the local bottled water (17%). Seventeen percent of women were using tap water for bottles but processed the water in various ways in the home. Caretakers reported that it took between 3 and 30 minutes to prepare a bottle of infant formula

and that the bottle was given within 2 hours of preparation. None of these caretakers treated the water they used for preparing formula.

LABORATORY

We sampled all 108 water sources used by the 120 study households and obtained available stored water samples from 87 (88%) of the 99 households that stored drinking water. Free chlorine levels in source water samples ranged from 0 to 0.6 mg/dl (median of 0.2 mg/dl). In stored water samples, free chlorine levels were considerably lower, ranging from 0 to 0.4 mg/dl (median of 0 .05 mg/dl) (Fig. 1). Detectable free chlorine was present in 105 (97%) of source water samples and in 45 (52%) of stored water samples.

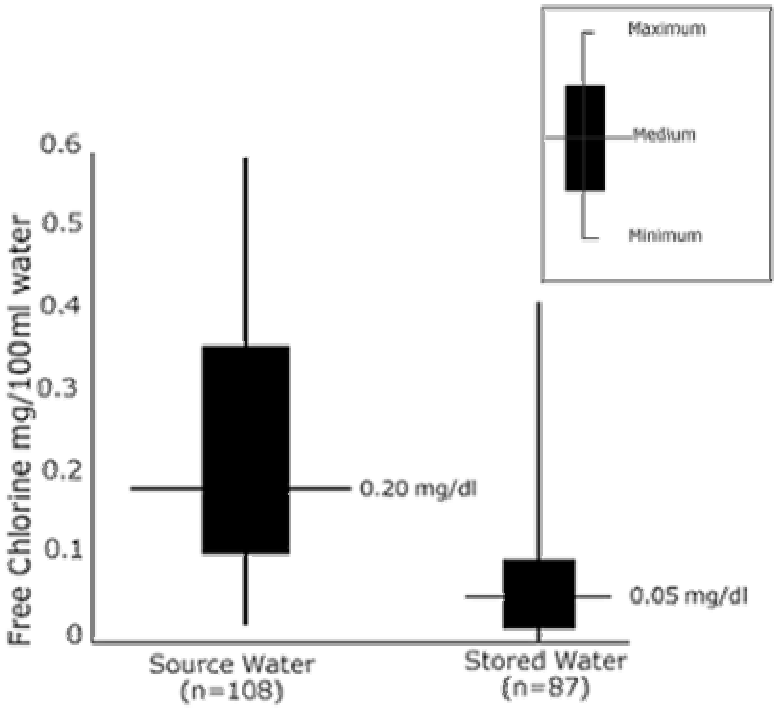

FIG. 1. Free chlorine levels, source and stored drinking water, Abidjan, Côte d'Ivoire.

Stored water was considerably more likely than source water to be contaminated with coliform bacteria and E. coli (Table 1). Coliform bacteria were detected in 64 (74%) samples of stored water and in 2 (2%) samples of source water (odds ratio [OR] = 147, 95% confidence interval [CI]: 32–941;p < .0001). *E. coli* was detected in 36 (41%) of stored water samples and in only 1 (1%) source water sample (OR = 76, CI: 11–1522;p < .0001). In 2 samples of stored water, both coliform bacteria and *E. coli* were too numerous to count, even at a 1:100 dilution equivalent to greater than 2×10^5 colony-forming units per 100 ml.

TABLE 1. Frequency of coliform bacteria and Escherichia coli in water samples, Abidjan, Côte d'Ivoire		
Result	**Source water n = 108 (%)**	**Stored water n = 87 (%)**
Coliform bacteria	2 (2)	64 (74)
Escherichia coli	1 (1)	36 (41)

We defined low free chlorine levels as <=0.10 mg/dl, the World Health Organization recommended level for prevention of cholera at community taps (19). Sixty-two (71%) stored samples had a free chlorine level <=0.10 mg/dl compared with 11 (10%) source water samples. The 2 source water samples containing either coliform bacteria or *E. coli* had free chlorine levels of only 0.01 mg/dl. Among stored water samples, residual free chlorine levels decreased and the frequency of contamination increased with longer storage times (Fig. 2). Chlorine levels were < 0.10 mg/dl in 70% of 46 samples that had been stored for 12 or more hours before collection compared with 19% of 37 samples that had been stored for less than 12 hours before collection (OR = 9.8, CI: 3.14–31.90;p < .001). Similarly, *E. coli* was more often detected in samples that had been stored for at least 12 hours (54% of samples) compared with samples that had been stored for less than 12 hours (27% of samples;p < .01). In addition, coliform bacteria were more likely to be detected in stored water samples from households where a cup was used to remove water by dipping (59 [83%] of 71 households) than from households where water was removed by pouring water (6 [50%] of 12 households; p = .06).

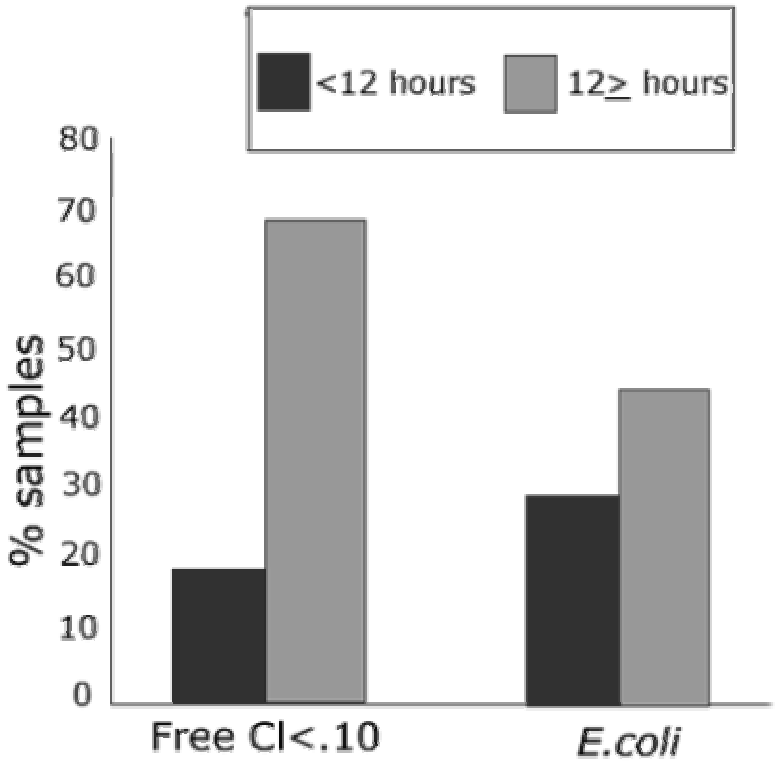

FIG. 2. Percentage of stored water samples with free chlorine <0.10 mg/dl and presence of Escherichia coli by duration of water storage, Abidjan, Côte d'Ivoire (n = 81). (Samples with duration of water shortage reported).

DISCUSSION

As in many clinics that provide services for HIV-infected women in developing countries, clinicians at the Koumassi maternal health clinic in Abidjan must weigh the risks of mother-to-child HIV transmission through breast milk versus those associated with the use of formula. Increasingly in health centers in Africa, formula-feeding is one of the options that is being considered by HIV-infected women to prevent postnatal transmission. To help evaluate one aspect of formula-feeding (i.e., the use and quality of water to make formula), we studied local drinking water quality, community water handling practices, and beliefs about water and formula-feeding. Several important facts about water quality, practices, and beliefs in this community emerged from our data.

First, most people in Abidjan collect municipal water for drinking, which is of generally good quality with adequate residual levels of free chlorine. Second, most people store this water at home in a variety of open containers, and during this time, chlorine levels dissipate and the water becomes progressively more contaminated. Third, most infants are given water to drink within the first week of life, and by 1 month of age, most infants have been given stored drinking water. Fourth, most mothers believe that breast-feeding is superior to formula-feeding and are aware of the risk of diarrhea associated with formula, particularly if it is prepared without proper care. Nonetheless, 10% of mothers in this survey were feeding formula to their infants, and none
were boiling the water used to prepare formula.

These findings have several implications for service providers in Abidjan. The municipal water service utility (SODECI) provides drinking water with generally adequate free chlorine levels to residents of neighborhoods included in this survey. Ninety-seven (90%) of 108 water samples collected at household or community taps had adequate chlorine levels and no detectable coliform bacteria; this represents a percentage that could be improved but is well above that of most other developing country municipal water systems. In other developing countries, contamination of municipal water systems is common; thus, our results may represent a best case scenario.

The majority of households (83%) stored drinking water. In the developing world, household water storage is a common practice, and this practice contributes to drinking water contamination (20,21). The longer the water was stored, the more likely it was to have low free chlorine levels and to be contaminated with coliform bacteria and E. coli. Forty-one percent of these households with children <=3 years old had detectable E. coli in the stored water samples we tested (a marker for fecal contamination) and therefore did not meet World Health Organization criteria for potability (<1 E. coli per 100
ml). In addition, coliform bacteria were detected in 74% of household stored drinking water samples. The presence of coliform bacteria in treated water supplies, although not a marker of fecal contamination, indicates that residual free chlorine levels are inadequate to protect against contamination at the point
of use.

Caretakers were not only breast-feeding infants; some caretakers gave infants drinking water during their first week of life, and most gave infants water for drinking by 1 month of age. Because most women give their infants water for drinking by 1 month of age, the relative contributions of formula and drinking water to early diarrheal disease cannot be determined in this setting. Nevertheless, efforts to improve drinking water should certainly benefit all infants because of better quality of formula and drinking water. Recent publications in Africa have reported that mixed feeding, or feeding breast milk and water, is a common practice [22]. Contaminated water used to make infant formula or given directly to infants may contribute to serious sequelae, including unnecessary diarrheal diseases and death. In addition, there may be an increased risk for HIV transmission; a recent publication from South Africa reported that mixed feeding may increase the risk of postnatal HIV transmission compared with exclusive feeding of breast milk in the first 3 months [23]. For women who choose to breast-feed, exclusive breast-feeding provides greater benefits for the mother and child [10]; however, further studies may be necessary to determine how to promote exclusive breast-feeding in these settings. The benefits of cleaner and safer stored drinking water would affect all children as well as other family members.

Limitations of our study include the fact that our survey was conducted in one large district in Abidjan and may not be generalizable to other neighborhoods where water from the municipal water system may not be obtained or where the quality of municipal water is different than that observed in our study. Also, this study was done over a single 8-week period during the dry season and does not guarantee that municipal water quality is consistent over the course of the year. Because of the wide variety of languages spoken by Koumassi residents, language barriers may have affected the validity of responses to some survey questions, particularly those on knowledge, attitudes, and practices. Despite these limitations, we obtained important data on water quality and practices that demonstrate the need for a convenient and inexpensive method to improve household drinking water storage to make drinking water and formula safer.

Treating water with a low-cost sodium hypochlorite solution (point-of-use chlorination) and storing treated water in vessels designed to prevent recontamination (safe storage) have been sustainable means of improving household drinking water quality and reducing diarrheal disease risk. This approach improved the bacteriologic quality of drinking water in studies in Bolivia [23] and Pakistan [24] and reduced diarrheal disease incidence in Bolivia [23] and Uzbekistan [25]. It has also been used to provide clean water for street-vended beverages in Guatemala [26] and for preparing oral rehydration solution in Guinea-Bissau [27]. An alternative to ensure safe water would be for mothers to routinely boil their water; however, boiling water is costly, time-consuming, and destructive to the environment [28]. In the setting of Koumassi, adequate free chlorine residual is generally present in municipal source water; additional point-of-use chlorination may not be necessary, and safe storage may be all that is required to improve stored drinking water quality. Women in Koumassi paid a median of 1200 CFA ($2.00) for their water storage containers. A safe storage vessel is currently being manufactured and sold in South Africa for $2.30 (Megapack, Nampac Corporation, Johannesburg, South Africa), which demonstrates that safe water storage could be an affordable alternative.

It is especially important that water used to prepare infant formula is safe. Formula provides a good medium for bacterial growth, particularly when kept unrefrigerated in a tropical climate. Formula-feeding increases the risk for diarrheal disease in developing countries, and it is likely that contaminated water supplies contribute to this increased risk [14,29]. In general, infants, the elderly, and those with immunocompromising conditions such as HIV infection are already at higher risk for acquiring diarrheal disease from contaminated water [30].

Maternal health settings in developing countries, especially those implementing formula-feeding programs to prevent mother-to-child HIV transmission, need to evaluate the water used to make infant formula and to make provisions for safe water. In addition, infant mortality rates should be monitored in settings that are using formula-feeding, both of breast-fed infants and formula-fed infants, so that the impact of the use of formula in settings where water quality is a concern can be assessed.

Note: Inclusion of trade names is for identification only and does not imply endorsement by the CDC or the Department of Health and Human Services.

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