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Can Locally Produced Chlorine Improve Water Sanitation & Hygiene Indicators in Health Care Facilities in Rural Chad?

Le chlore produit localement peut-il améliorer les indicateurs WASH dans les établissements de santé du Tchad rural ?

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Mots clés: Tchad, électro-chlorateur, hypochlorite de sodium, établissement de santé, hôpital

ABSTRACT

Background. Chad faces an extreme lack of basic infrastructure. In 2019 its Human Development Index was 0.398, positioning it at 187 out of 189 countries. Chad's health care facilities (HCF) often don't have water treatment or surface disinfection. **Methods.** The private company Watalux SA, sponsored by UNICEF Chad and supported by staff members from Antenna Foundation, measured the Water Sanitation and Hygiene (WASH) indicators in 68 HCFs across three districts of rural Chad and installed electro-chlorinator devices enabling local production of sodium hypochlorite. Watalux subsequently evaluated this program aimed to reduce hospital-acquired infections and water-related illness. **Results.** Among the HCFs included in the diagnosis phase, 73% had latrines, 67% had water tanks, and almost all of them used chlorine for surface disinfection on a regular basis, but only half the HCFs used chlorine for water treatment. The main barriers that prevented people from using chlorine were: running out of the product; this was followed by lack of staff training, and finally the chlorine's smell. After the installation, 61% of HCFs produced sodium hypochlorite every day and 97% of operators knew how to produce sodium hypochlorite. After the project's implementation, all HCFs produced sufficient quantities of chlorine. **Conclusion.** The installation of electro-chlorinator devices improved WASH indicators. The project also clearly increased surface disinfection. However, the use of chlorine in drinking water treatment might face other challenges beyond product availability (e.g. acceptance of smell by the local population and staff training).

RÉSUMÉ

Contexte. Le Tchad fait face à un manque extrême d'infrastructures de base. En 2019, son indice de développement humain était de 0,398, le positionnant à 187 sur 189 pays. Les établissements de santé (HCF) du Tchad ne disposent souvent pas de traitement d'eau ou de désinfection de surface. **Méthodes**. La société privée Watalux SA, dans le cadre d'un projet financé par l'UNICEF Tchad et soutenue par des membres du personnel de la Fondation Antenna, a mesuré les indicateurs d'Eau, d'Assainissement et d'Hygiène (WASH) dans 68 établissements sanitaires de trois districts ruraux du Tchad et a installé des appareils d'électrochloration permettant la production locale de l'hypochlorite de sodium. Watalux a ensuite évalué ce programme visant à réduire les infections nosocomiales et les maladies liées à l'eau. **Résultats**. Parmi les établissements sanitaires inclus dans la phase de diagnostic, 73 % disposaient de latrines, 67 % avaient des réservoirs d'eau et presque tous utilisaient régulièrement du chlore pour la désinfection des surfaces, mais seulement la moitié des établissements sanitaires utilisaient du chlore pour le traitement de l'eau. Les principaux obstacles qui empêchaient les gens d'utiliser du chlore étaient : le manque de produit ; cela a été suivi par le manque de formation du personnel, et enfin l'odeur du chlore. Après l'installation, 61 % des HCF produisaient quotidiennement de l'hypochlorite de sodium et 97 % des exploitants savaient produire de l'hypochlorite de sodium. Après la mise en œuvre du projet, toutes les installations sanitaires ont produit des quantités suffisantes de chlore. **Conclusion**. L'installation d'appareils d'électro-chloration a amélioré les indicateurs WASH. Le projet a également nettement amélioré la désinfection des surfaces. Cependant, l'utilisation du chlore dans le traitement de l'eau potable pourrait faire face à d'autres défis au-delà de la disponibilité du produit (par exemple, l'acceptation de l'odeur par la population locale et la formation du personnel).

INTRODUCTION

Chad is literally one of the most impoverished countries in the world. In 2019 Chad's Human Development Index was 0.398, positioning it 187th out of 189 countries. The average life expectancy is 59.6 years for both sexes. Children in Chad are particularly hard hit with 39.8% of the under 5-year-olds malnourished and presenting moderate to severe stunting. The country faces a lack of basic infrastructure and to date, there is no reliable data on the percentage of the population that drinks water from an improved source, nor how many are using an improved sanitation facility (1).

There is a staggering absence of data about where Chad stands in terms of nosocomial (hospital-acquired) infections. As in many other low-income countries, government surveillance systems for nosocomial infections are almost non-existent, but it is estimated that 16% of patients acquire infections while seeking care in African hospitals (2). In 2014, the general Chadian government expenditure on health was 8.9% and only 24.3% of births were attended by skilled health personnel (1).

The latest figures, from 2020, estimate that 43% of the Chadian population did not have access to improved drinking water sources (3).This means that nearly half of the country's population regularly consumes water that is not safe for drinking. Furthermore, there are large discrepancies between urban and rural areas, the latter often being in significantly worse situations (4).

Electro-chlorinator devices transform salty water into sodium hypochlorite through electrolysis and can be installed in a wide diversity of healthcare facilities. The device is adapted to the difficult contexts found in low-income countries requiring little training or maintenance costs. In Burkina Faso, the provision of electro-chlorinator devices in twenty-six health care facilities (HCFs) allowed these HCFs to have access to sufficient amounts of sodium hypochlorite, which promoted compliance with hygiene practices. In addition, the initial investment cost could be offset within the first year (5). Similarly, two university hospitals in Mali performed microbiological control of surfaces and medical devices before and after disinfection with chlorine produced locally by electrolysis and observed the reduction in the number of pathogenic germs present. They concluded that the availability of a high-quality chlorine solution can be an important asset in the establishment of an effective system for the protection of patients and nursing staff (6).

In the present article, we describe the situation of 68 HCFs and evaluate a program in rural Chad to reduce acquired infection at the point of care and water-related illnesses. The authors monitored electro-chlorinator devices that produced chlorine locally in sixty-seven HCFs. The extent to which access to chlorine can improve water sanitation and hygiene indicators was at the heart of our research.

The results reported can be a source of data on the HCF assessed and help inform programs seeking alternative approaches for low-income rural communities.

METHODS

Setting

This paper assessed 68 health care facilities between July and August 2018. These HCFs are located in three sanitary districts and distributed as follows: 10% (7/68) located in Bokoro, 32% (22/68) in Moussoro, and 58% (39/68) in Mao (Figure 1). In these facilities, baseline WASH indicators were measured in July 2018 and the suitability of its infrastructure to have an electro-chlorinator device (WATA™) installed was evaluated. The HCFs were identified with the help of UNICEF Chad.

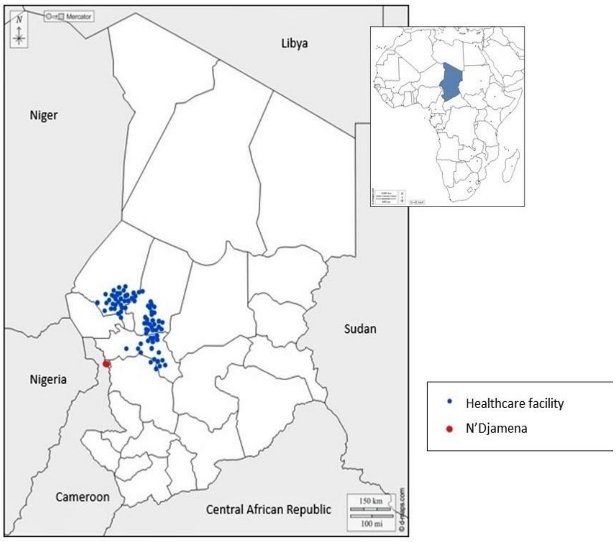

Figure 1 - Location of Health Care Facilities (blue dots) & the capital N'Djamena (red dot)

Project design

The project time frame was 1) diagnosis, 2) installation followed by training, and finally 3) two follow-up periods. This study follows the before-and-after comparison design.

Diagnosis

The project used a data management platform called mWater to collect WASH indicators like the presence of latrines and water tanks, usage of chlorine for surface disinfection, and whether the water was analyzed/treated.

A baseline survey was conducted to assess the needs of HCFs as well as to better understand the main barriers to the use of chlorine to disinfect surfaces and water treatment.

The main requirements for the installation were the presence of two separate rooms to carry out the electrolysis: one room for the production of chlorine and another for the batteries and the control box. Furthermore, it was necessary to have someone in charge of the production. The room was also evaluated to see if it would be suitable for storing solar panels and equipment in a safe and secure environment. If the HCF did not fit the project's requirements, the center was replaced by a different one.

Installation

Electro-chlorinator devices were installed in all centers that met the requirements as well as the centers that were able to adapt their installations to fit the project's requirements. The choice of the device was in accordance with the size of the center. Training for the staff was also provided (Figure 2).

Figure 2 - Photo of an electro-chlorinator device and a production room.

Description of the devices

Two types of devices, WATA™, were used in the program. All of them produce sodium hypochlorite concentrated at 6 g/L:

WATA-Standard can produce 2 L of disinfectant within 2 hours, producing about 8L of disinfectant daily.

WATA-Plus produces 15L of disinfectant in 4 hours, producing up to 30L daily.

It is estimated that a WATA-Standard and WATA-Plus powered by a solar grid will last for 14 years, performing one cycle daily producing sodium hypochlorite at 0.14 dollars/L and 0.07 dollars/L respectively.

Training

More than one staff member from each HCF was trained in production, dilution, and sample collection techniques. This training allowed them to operate the devices, control the quality of chlorine batch produced, and learn about the conditioning of sodium hypochlorite.

Follow-up

Follow-ups were performed twice. The facilities were first revisited after five months, then eight months after the installation (July 2019 and November 2019). The facilities were revisited to evaluate if the WATA devices and solar kits were operating in good conditions, if the staff was successfully operating the devices, and if the center was independent in producing chlorine.

RESULTS

Baseline assessment

Among the 68 health care facilities (HCFs) included in the diagnosis phase, 73%(50) had latrines, 67%(46) had water tanks, but only two performed water analysis. Almost all of the HCFs use chlorine for surface disinfection 95%(64), but only half use it for water treatment 50%(34) (Table 1). The GPS localizations of the facilities studied is available in Supplemental Material 1 and the GPS localization of all facilities identified in the program can be find in Supplemental Material 2.

Table 1: Wash indicators collected in 68 health care facilities in Chad

WASH indicators of the health care facilities (N=68)	N(%)
Presence of latrines	50 (73)
Usage of chlorine for surface disinfection	64 (95)
Perform water analysis	2 (2.9)
Perform water treatment	34 (50)
Presence of a water tank	46 (67)

Product shortage was among the main barriers reported to chlorine usage 51%(35), followed by lack of staff training, and finally the "bad smell of chlorine" (Table 2). Only 12 centers reported not having problems with chlorine usage.

Table 2: Main barriers reported by the centers in chlorine usage.

Main barriers concerning chlorine usage (N=68)	N(%)
Product shortage	35 (51)
Lack of training	27 (39)
Bad smell	8 (12)

Installation and monitoring

The diagnosis phase was performed in 68 Health Care Facilities (HCFs), but installation only took place in 67 HCFs because one of them couldn't comply with the installation requirements.

In the end, 67 electro-chlorinator devices were installed in rural Chad. Two models of the device were installed: 64 WATA-Standard and three WATA-Plus. During the first follow-up, five months after installation, 97%(65/67) of WATA devices and 89%(60/67) of solar kits were in good condition and operating. Sodium hypochlorite was daily produced in 61%(41/67) of health care facilities and up to three times a week in 31%(21/67) of them. Almost all operators, 97%(65/67), knew how to produce sodium hypochlorite and were fully trained. WATA devices were perceived as very useful by 91%(61/67) of health centers and all of them (100%) were sufficient in chlorine production.

In the second follow-up, nine months after installation, only one WATA device was out of service, waiting to be replaced, and all solar kits were in good condition and operating. Although, since the installation, eleven repairs had been done. All operators knew how to produce sodium hypochlorite and all HCFs were producing sufficient quantities of chlorine.

DISCUSSION

This study is part of a program that assessed water sanitation and surface disinfection in 68 HCFs in rural Chad. We identified that chlorine shortage and lack of staff training faced by them in the regions of Bokoro, Moussoro, and Mao represent important setbacks in the control of healthcare-acquired infections and water treatment. The aim of the program was to help those HCFs to become independent in the production of sodium hypochlorite.

The "bad smell" caused by chlorine was also mentioned in the survey during the diagnostic phase conducted to understand the main barriers concerning chlorine usage. Because 95% of facilities use chlorine for disinfection when it is available and only 50% of them perform water treatment, we assume that the "bad smell" is related to the use of high amount of chlorine in the process of water treatment by staff members. It was already reported in the literature that along with financial and time costs of usage, taste and smell are barriers to point-of-use water chlorination (7). Indeed, in Zambia, 32% of individuals that stopped using sodium hypochlorite reported that it was because of the smell (8). Another study conducted in Dhaka, Bangladesh, found that lower target doses for chlorine could potentially increase acceptability, usage, and demand for such products. Aversion to the taste or smell of chlorinated water can limit the use of chlorine treatment products (9). Therefore, staff training might play a pivotal role in water treatment as it is possible to find a threshold of chlorine dosage that improves acceptability by decreasing the "bad smell," without compromising water quality. The program was focused on staff training for local chlorine production and equipment maintenance, and the extensive training and follow-up were key elements to achieve success in chlorine production and usage. In future interventions, attention must be made to water chlorination strategies to reinforce that sodium hypochlorite is also used for water treatment.

Before the implementation of the program, the high incidence of chlorine shortage, reported in 35 out of 68 (51%) HCF, might have contributed to infection through contaminated water, hands, and medical equipment. In those conditions, HCFs become an infection hub, and patients seeking treatment fall ill, and potentially die, from healthcare-acquired infections. Cronk & Bartram (2018), using nationally representative data from six middle and low-income countries, found that only 2% of HCFs provide the combination of water, sanitation, hygiene, and waste management services. It was also found in the same study using a bigger number of countries that there are significant inequalities; HCFs in rural settings had significantly lower odds of having a basic water service as compared to HCFs in urban settings (4). Because Chad was not represented in this study, due to data unavailability, the estimates may be inaccurate but at the same time, they reflect a reality that we found in our program: water tanks and latrines were not always available in HCFs and water analyses were rarely performed. Geographical conditions might explain the shortage of chlorine in the HCFs assessed as Chad ranks 5th among the largest countries in Africa, covering 1,284,000 km². Only 664 km of roads are permanently paved, while 1,609 km of roads remain unpaved. Communications between the different parts of the country are sometimes difficult, if not possible at all, for several months because flooding makes many of them impracticable. In addition, the supply of goods in provinces is often related to informal businesses. Often, the best ways to transport supplies are the two rivers of the country: the Chari and the Logone. These rivers constitute the country's main arteries but there are frequent problems of water levels between the dry season and the rainy season. Furthermore, during the dry season, these rivers are completely unavailable for navigation (10). Therefore we can assert that the countryside is difficult to reach and products that are not locally produced can easily become scarce.

The cost of supplying "environmental health" to HCFs are extremely important to budget for service delivery, but when it comes to low-income countries there is a lack of available data (11). Indeed, it was not possible to find another study in Chadian HCFs where we could compare the implementation of similar technology from installation through operations and maintenance. In Burkina Faso, a cost-benefit analysis allowed the comparison of the costs incurred by health care facilities buying sodium dichlor-oisocyanurate tablets and those using electro-chlorinator devices. Globally, it was reported that WATA-Standard solar allowed savings of 2.66 euros daily with an estimated offset of investment after 381 days while WATA-plus solar saved the HCFs 13.31 euros daily with an investment offset after 254 days (5). In Mali, when produced in the hospital, 1 liter of bleach costs fourteen times cheaper than the product from the local market (6). Although important savings are reported, the possibility of local production in the case of Chadian HCFs is what seems to play a major role in the curb of hospital-acquired infections.

The literacy rate in Chad among those 15 years and over is of only 41.5% (10), so an important aspect when implementing a program is adaptability to this context. The follow-up visits were also to check if operators were fully capable of producing the sodium hypochlorite as it is described in the procedures. With all of them able to comply, it's a technology that can be easily implemented in Rural Chad. In addition, 66 out of 67 of the devices were fully operating after nine months which indicates that the material can resist the meteorological conditions of the region. Furthermore, this success also underlines the importance of the strict requirements that HCFs need to meet before installation, like a room dedicated to the electrolysis and someone in charge of the production.

CONCLUSION

The installation of electro-chlorinator devices in Health Care Facilities (HCFs) in rural Chad and extensive staff training performed allowed those facilities to become self-sufficient in sodium hypochlorite production which can greatly contribute to the improvement of Water, Sanitation and Hygiene (WASH) indicators. HFCs will certainly use the chlorine for surface disinfection as it is a practice already implemented in the centers. However, the use for treating drinking water might not be as straightforward. Indeed, extra attention should be given in future programs to other barriers beyond product availability that should be taken into consideration, such as the rejection by end users of drinking water that smells or tastes of chlorine.

DISCLOSURE

The data collection was made possible thanks to the support of UNICEF and was performed by a local firm called COMECA using the online platform called Mwater.

The project itself was funded by UNICEF under the umbrella of the Republic of Chad's Ministry of Health.

Conflict of interest

This research was financed, conceptualized and analyzed by the staff of the implementing partners: Watalux SA (a private company based in Switzerland that manufactures and distributes electro-chlorinators) as well as the Antenna Foundation (a non-profit organization, also based in Switzerland, that aims to disseminate innovations that improve the essential needs of the world's most vulnerable populations).

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SUPPLEMENTAL MATERIAL (1)

Table 1: Geolocations (Coordinates GPS) of health care facilities which were studied

Site Number	HCF Name	District	Latitude	Longitude
1	Abgode	Bokoro	13.0208	16.8345
2	Amkouakib	Bokoro	12.9509	16.6133
3	Amsilep	Moussoro	13.3771	16.7860
4	Ardebe	Bokoro	12.2283	17.0248
5	Arrada	Bokoro	12.9486	16.6984
6	Barkabelou	Mao	14.2964	15.1484
7	Barrah	Mao	14.2893	15.2323
8	Birbassar	Mao	13.9011	15.4463
9	Blatoukouli	Mao	14.2281	15.1999
10	Bogolet	Mao	14.1922	15.0949
11	Boulougou	Moussoro	13.4179	16.3836
12	Bouroudou	Mao	13.9451	15.5571
13	Bourounkou	Mao	14.1491	15.7823
14	Dar Salam	Bokoro	12.9500	16.8886
15	Digueiri	Mao	13.9625	15.5821
16	Djigueret	Mao	14.2203	15.0481
17	Fizigui	Moussoro	13.1529	16.5814
18	Gaba	Moussoro	13.9960	16.4787
19	Guiladinga	Mao	13.9929	14.5496
20	Guina	Moussoro	13.1702	16.9270
21	Hille Afe	Moussoro	13.9375	16.5618
22	Isne Mazaraf	Bokoro	12.9376	16.8644
23	Kagaye	Moussoro	13.5867	16.4967
24	Kakari	Mao	14.1293	15.9077
25	Kamkalaga	Moussoro	13.2701	16.4180
26	Kawatchou	Moussoro	13.3492	16.8753
27	Kekedina	Mao	13.8428	14.8381
28	Keliganga	Mao	13.8698	15.0507
29	Kollet	Mao	14.1067	15.0076
30	Kopoye	Mao	14.2623	15.9702
31	Kourikouri	Mao	14.1056	15.1746
32	Latoum	Mao	14.2094	15.5119
33	Ligra	Mao	14.1994	15.3128
34	Madrianga	Moussoro	13.0758	16.5687
35	Maga	Mao	14.0384	15.0824
36	Maguiyanga	Mao	13.9611	15.5538
37	Mao Centre	Mao	14.1268	15.3109
38	Mao Mosquee	Mao	14.1177	15.3149
39	Mao Moto	Mao	14.1165	15.3113
40	Melleah	Mao	14.2583	15.5574

41	Moussoro Urbain	Moussoro	13.6433	16.4933
42	Nguelea	Mao	14.0746	15.6065
43	Sidi Malari	Mao	13.8538	15.4503
44	Tarfe	Mao	14.2312	15.3421
45	Tcheli	Mao	13.7299	15.4499
46	Tchie Koukoul1	Mao	14.1079	15.6903
47	Tchie Madranga	Mao	14.1617	15.7558
48	Tchiri Salmari	Mao	14.0475	15.2657
49	Tchiworou	Moussoro	13.5546	16.4422
50	Telelenga	Mao	14.1253	15.4955
51	Toukouli	Mao	13.9821	15.5037
52	Wadicha-gara	Moussoro	13.2701	16.4687
53	Wadjigui	Mao	14.3199	15.3999
54	Woutou-koulfou	Mao	14.0507	15.2084
55	Yougoum	Mao	14.2277	15.9039
56	Amkoua Deguechie	Moussoro	13.3078	16.5956
57	Bir Hache	Moussoro	13.6725	16.6457
58	Boholo Himede	Bokoro	12.2729	16.5783
59	Chagara	Moussoro	14.0364	16.4193
60	Chiraguin	Moussoro	13.8107	16.6103
61	Dogo	Moussoro	13.0758	16.4225
62	Dolock	Moussoro	13.1775	16.7172
63	Fassaladjoul	Moussoro	13.2834	16.5472
64	Gozbila	Moussoro	14.0781	16.5394
65	Grantessi	Moussoro	13.9416	16.6946
66	Tchara	Mao	13.8271	15.3920
67	Toula	Mao	13.7650	15.3594
68	Yarwai	Mao	14.0274	15.6352

HCF : Health Care Facility

SUPPLEMENTAL MATERIAL (2)

Table 2: Geolocations (Coordinates GPS) of health care facilities which were identified (but not studied)

Site Number	HCF Name	District	Latitude	Longitude
69	Abirebi	Bokoro	12.2950	16.7615
70	Binda	Mao	14.1336	15.4550
71	Bisney	Bokoro	12.6763	16.1681
72	Bokoro I	Bokoro	12.3791	17.0593
73	Bokoro Ii	Bokoro	12.3803	17.0544
74	Dilema	Bokoro	12.1031	16.8614
75	Galdam	Bokoro	12.4202	16.1693
76	Gambir	Bokoro	12.5352	16.7510
77	Kindji	Bokoro	12.0077	16.7579
78	Maïgana	Bokoro	12.1633	16.4643
79	Moyto	Bokoro	12.5951	16.5500
80	Ngoura	Bokoro	12.8793	16.4536