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# Barriers and Facilitators to Chlorine Tablet Distribution and Use in Emergencies: A Qualitative Assessment

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**Abstract:** Chlorine tablets are commonly distributed for household water treatment in emergencies. However, confirmed use after distribution ranges widely (from 7–87%), which raises concerns about chlorine tablet effectiveness, as measured by acceptance and appropriate use. To investigate chlorine tablet effectiveness, we conducted nine key informant interviews (KIIs) on tablet distribution in emergencies in general, five KIIs on chlorine taste and odor acceptance and rejection specifically, and a literature review on chlorine taste and odor concerns. We found: (1) chlorine tablets are regarded as one of the most effective water treatment methods and are often considered appropriate in emergency response, (2) dosing confusion and taste and odor rejection are perceived as the main problems limiting effectiveness, and (3) the primary solutions suggested for these problems were social and behavioral. We recommend that social and behavioral scientists are routinely integrated into chlorine tablet programming to improve user feedback and behavioral interventions for chlorine tablet promotion in emergencies. We also suggest that more research is conducted on chlorine taste and odor rejection in vulnerable populations, and that improved guidance is developed to facilitate intra-agency coordination and select, promote, and monitor tablets appropriate for each context.

**Keywords:** chlorine; chlorine tablets; drinking water; emergency; outbreaks; water disinfection; drinking water; water treatment

## 1. Introduction

Safe drinking water is a priority need to prevent disease during emergencies, such as natural disasters, disease outbreaks, and complex emergencies [1]. Chlorine is often used to treat drinking water, as it not only inactivates most bacteria and viruses that cause diarrheal disease, but the remaining free chlorine residual (FCR) also provides continuing protection against recontamination during transport and in storage [2–4]. Chlorine tablets (such as the sodium dichloroisocyanurate (NaDCC) Aquatabs®, Medentech Ltd., Wexford, Ireland) are commonly distributed for household water chlorination in emergencies because they are widely available, cost-effective, easily transported, and simple to use—in 2018, Aquatabs were used to disinfect an estimated 30 billion liters of water [2,5,6]. Instructions for use are to add one tablet to the appropriate quantity of water, mix by briefly shaking or stirring, and wait for 30 min before consumption [7].

Chlorine tablets are one of the most commonly evaluated water, sanitation, and hygiene (WASH) interventions in emergency contexts [8]. While they are efficacious and practical, a recent systematic review found heterogenous results across programs, with confirmed use of chlorine tablets ranging from 7–87% across six programs that were evaluated [8]. This suggests that while chlorine tablets can be effective for water treatment in emergencies, appropriate use is variable, and effectiveness for preventing waterborne disease transmission is dependent upon proper tablet distribution and use. Thus, effectiveness often depends on context. Use in the evaluated programs was highest when tablets were distributed with household promotion and/or users had prior knowledge of water treatment. An aversion to the taste and odor of chlorine was reported as a barrier in nearly half the evaluations. Distribution of appropriate supplies for water treatment was also identified as a challenge—in four evaluations, recipients did not have water storage containers appropriate for the tablets distributed, and in two contexts multiple chlorine doses were available and caused confusion regarding appropriate use [8].

This evidence demonstrates a wide range of program effectiveness and begins to point to factors that enable programmatic success [8]. However, these results were mostly quantitative, and cannot provide rich information on the enabling factors leading to program success or failure in a diverse set of environments. To enable a thorough understanding of chlorine tablet effectiveness and help interpret results found in previous quantitative studies, accessing the qualitative knowledge of WASH practitioners is essential [9]. To our knowledge, there has not been any previous systematic qualitative research on chlorine tablet program effectiveness. Qualitative data that is systematically collected and analyzed to synthesize expert experience on chlorine tablet programs can be used to characterize and investigate the scope of these challenges and inform future research seeking to contextualize and improve the effectiveness of programs.

To better understand the distribution, acceptance, and use of chlorine tablets in emergency settings and identify factors associated with program success, we undertook an exploratory study to identify common challenges and successes in tablet programs. We used key informant interviews (KIIs) with emergency WASH professionals experienced in chlorine tablet distribution to discuss chlorine tablet distributions in general and concerns about taste and odor acceptance specifically and conducted a literature review to synthesize evidence related to taste and odor concerns in water treatment with chlorine tablets.

## 2. Materials and Methods

We conducted: (1) KIIs on chlorine tablet distributions in general, (2) taste and odor specific KIIs, and, (3) a literature review on chlorine taste and odor acceptance and rejection. The KIIs were approved by the Institutional Review Board at Tufts University (#1801039 and #1706022).

### *2.1. General Key Informant Interviews*

A 30-question semi-structured KII guide was developed to investigate important topics within chlorine tablet programming identified when reviewing the literature and in the systematic review by Yates et al. Questions were designed to explore informant experiences within each topic to identify factors leading to challenges and successes in programming in different emergency contexts. The KII guide included sections on typical household water treatment in emergencies, benefits and drawbacks of treatment methods, distribution of chlorine tablets, perceptions of factors leading to program success or failure, community acceptance, and suggestions for solutions to challenges limiting effectiveness. The WASH professionals involved in a working group led by Tufts University to develop guidance on chlorine tablet distributions in emergencies were contacted by email and invited to participate; snowball sampling was used to find additional informants. Interviews were conducted by Skype (Palo Alto, CA, USA) or phone and recorded using CallNote (Newton, MA, USA), Quicktime Player (Cupertina, CA, USA), or TapeACall (New Jersey, NJ, USA). Recorded interviews were transcribed using Temi (San Diego, CA, USA), cleaned, and uploaded to NVivo (Burlington, MA, USA) for qualitative analysis.

Qualitative content analysis was used because of the lack of an initial evidence basis to pre-select themes and the wide range of topics of interest [10]. Interview segments were coded into themes that emerged during analysis and results are presented by themes identified.

### 2.2. Taste and Odor Specific Interviews

As taste and odor are commonly discussed among responders as leading to concerns with chlorine adoption, we conducted specific interviews on chlorine taste and odor acceptance and rejection. A literature review was conducted, as described below, and used to identify key topics of investigation. A 28-question semi-structured KII guide was developed, including sections on the topics of typical water treatment in emergencies, benefits and drawbacks of treatment methods, user perceptions of water and how this information is collected, chlorine detection and rejection prevalence and thresholds, and suggestions for solutions to taste and odor challenges. Questions were designed to explore the range of informant experiences with user responses to chlorination. WASH professionals were contacted by email with an invitation to participate, and snowball sampling was used to find additional informants. Interviews were conducted on Skype and recorded using Amolto Call Recorder (Russia). Data analysis was conducted as described above.

### 2.3. Taste and Odor Literature Review

To supplement the chlorine taste and odor interviews, we report here the results of a search of the peer-reviewed literature addressing the issue of chlorine taste in treated water and taste and odor rejection conducted prior to the KIIs. Two databases (PubMed and Global Health) were searched using the string (chlorine AND water AND (taste OR odor OR flavor)). Search results were examined for relevance, and reference tracing was completed to identify further relevant manuscripts.

## 3. Results

### 3.1. Key Informant Interviews

For the general KIIs, 20 individuals were contacted and 9 KIIs were conducted. Eight out of nine informants worked with non-governmental organizations (NGOs); the remaining informant was an industry representative. Informants worked primarily as WASH practitioners or donors. For the taste and odor KIIs, 26 individuals were contacted and 5 KIIs were conducted. Three out five informants worked for NGOs, the remaining were involved in applied WASH research. One informant participated in both KIIs. Themes that emerged from the two sets of interviews were similar; therefore, we chose to present them together, noting where results from the two groups differed.

In total, eight themes evolved from KII responses, including: (1) treatment options, (2) chlorine tablet use in emergencies, (3) distribution and program monitoring, (4) technical and social challenges, (5) tablet dosage, (6) intervention effectiveness, and (7) recommendations for distributors and implementers (Figure 1). Each is further described below.

#### 3.1.1. Treatment Options

When asked about water treatment options, informants noted that the first priority is finding a satisfactory water source that can be accessed quickly. They highlighted the importance of assessing each emergency to determine the most appropriate treatment option. Most informants considered household water treatment (HWT) an effective short-term solution prior to the installation of bulk water treatment systems (e.g., piped water to the home or tap stands) or when bulk systems cannot be used. Informants also noted that, in conditions with low hygiene and sanitation coverage, bulk treatment may be less effective because recontamination before the point-of-consumption is likely.

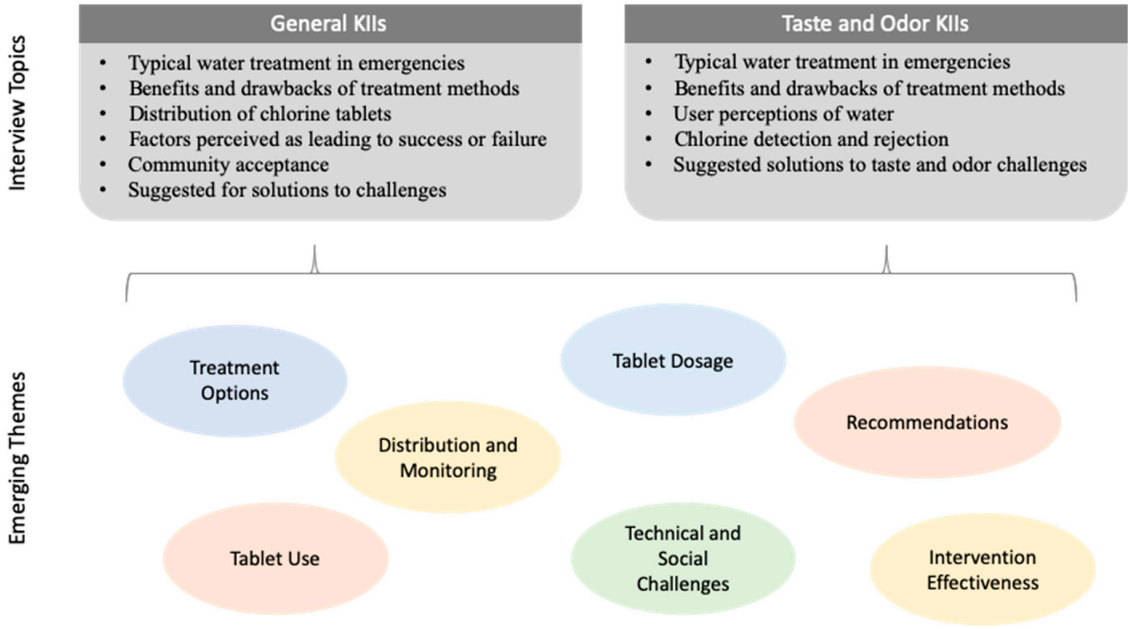


**Figure 1.** Key informant interview question topics and emerging themes.

HWT methods most commonly mentioned were chlorine-based treatments (e.g., liquid bleach, chlorine tablets, and flocculant-disinfectant combinations) and filtration (e.g., biosand, membrane, pot, and ceramic filters). Some informants also mentioned boiling and solar disinfection (SODIS). Most informants considered chlorine-based treatments most effective; they noted that although an advantage of filters is the visible change in water quality, the need to maintain and replace filters can be complicated and reduce effectiveness. Taste and odor informants noted that, when there are no alternative water sources, people are forced to drink treated water provided by WASH organizations, but it is still important to make sure this water is acceptable to users.

> "It's difficult to make generalizations . . . but the approach would be to identify a source and then assess whether, A, [there's] enough quantity, then B, go towards making efforts to improve the quality"
>
> —WASH Practitioner (Taste and Odor KII)

> "The advantage of [HWTS] specifically is when you know you need to transform the quality of your water at the household level in areas where either you cannot update facilities, or you don't have the time to."
>
> —WASH Practitioner (General KII)

> "Truly speaking, except chlorination, there was no other effective treatment which has been adopted in any of the places because it was easy to handle, easy to take from one place to another, easy to operate."
>
> —WASH Practitioner (General KII)

#### 3.1.2. Chlorine Tablet Use in Emergencies

Most informants felt that tablets were easier to implement than other chlorine-based treatments due to their size and simplicity of use and noted that they are relatively inexpensive and available through import or local markets. Chlorine's effectiveness against pathogens of concern and residual protection were also highlighted as important advantages. However, informants stated that chlorine tablet utility differed by context, noting people seemed more likely to use them if they had prior experience with tablets or were in emergency (rather than development) settings. Informants noted

that there is a lack of guidelines or standard practice by type of emergency. Utility for HWT was perceived as: lowest in camp settings caused by conflicts (when people are closely grouped and bulk water provision is preferable and feasible), and highest in both disaster relief (when populations are often widely distributed and water quality low), and disease outbreaks (when users are most aware of the positive impact of water treatment).

> "[It's] cheap, easy to use, highly effective against most of the pathogens we encounter in our [emergency] settings"
>
> —WASH Practitioner (Taste and Odor KII)

> "It doesn't pose a big challenge because it is easy to handle, easy to maintain, and you can easily train. You can inform the participants this is how we would be using it and there's nothing hidden."
>
> —WASH Practitioner (General KII)

> "I would say in the conflict settings it's just kind of set up differently. So, I would say mainly in natural disasters, it is quite common to be doing really a household level distribution."
>
> —WASH Practitioner (General KII)

#### 3.1.3. Chlorine Tablet Distribution and Program Monitoring

Chlorine tablet programs involve tablet distribution, promotion, and post-distribution monitoring. For distribution, informants noted that providing tablets as a typical one-time distribution non-food item without proper instructions can lead to improper use and inadequate acceptance. Rather, monthly or weekly distribution during which users are reminded of how to use the product and able to ask questions was preferred. Informants noted that conducting monitoring or promotion through household visits requires financial support.

Informants consistently cited promotion, including ensuring acceptance and correct and consistent use, as both the most challenging and the weakest area of programming. First, informants noted that individuals conducting training typically lack an understanding of, or specialized training in, the technical and/or behavioral aspects of water treatment. Thus, while hiring local community members for training and monitoring was recommended, informants also indicated a particular need for input from social scientists equipped to assess cultural and educational needs. Second, although chlorine-based treatments are commonly promoted as a means to prevent sickness, health effects can be difficult for users to observe. Chlorine tablets have also been mistaken for pills and ingested by users when trainings are misunderstood. Informants proposed that not just health, but social benefits, should be emphasized in training.

Informants noted that monitoring of effectiveness is rarely undertaken. Experiences with chlorine tablet use varied—some informants reported higher use of tablets compared to other HWT products, while others experienced low to moderate use. Monitoring was mentioned as important both as a reminder of appropriate use and to ensure that dosage recommendations are providing sufficiently chlorinated water. As chlorine demand is dependent on water quality, dose adjustments may be required for extended interventions. Informants stressed the importance of monitoring for program success, while noting it is complex and expensive.

> "One of the biggest limitations on Aquatabs is education. You are still trying to educate people to do something with the water. And the second thing is you are trying to convince them to do it on a continuous basis."
>
> —WASH Practitioner (General KII)

> "In our literature and guidelines, we always have statements that we should consider user input. We don't often do that until things are stable enough."
>
> —WASH Practitioner (Taste and Odor KII)

#### 3.1.4. Technical and Social Challenges

A significant challenge noted by informants was that chlorine taste and odor can be unpleasant to users. Informants noted this was particularly of concern when water is highly contaminated before chlorination, and disinfection byproducts and remaining FCR create a taste and odor that cause rejection. Prior experience and positive and negative associations with chlorine appeared to impact the level of chlorination at which respondents would avoid drinking water. Chlorine tastes and odors were frequently objectionable at even relatively low levels to populations without experience with chlorinated water. Informants described hearing negative false rumors about chlorine (e.g., that chlorine caused infertility) that made users less likely to drink chlorinated water. Less commonly, informants described that users with a positive association with chlorine's health benefits may even prefer water in which they can detect chlorine. One taste and odor informant described users in Haiti as purposely overdosing water with chlorine, because the taste and odor was reassuring that water was safe to drink.

All informants indicated that failing to address chlorine taste and odor concerns can be dangerous, because safe, chlorinated water may be rejected, and users may seek alternative water from unsafe sources. One taste and odor informant described a situation in South Sudan where user rejection of chlorinated water and subsequent use of livestock pond water was linked to a Hepatitis E outbreak. Another recalled that users displaced after flooding in Pakistan in 2010 would throw out chlorinated water, which they suspected was linked to a subsequent cholera outbreak. One informant noted that their organization tried to respond to rejection, when it occurred, by reducing chlorine levels and that if this is done without confirming that water remains sufficiently chlorinated, this reactive approach can impact water safety.

A second challenge informants noted was ensuring correct and consistent use. Informants explained that because treatment with chlorine tablets does not visibly change water, much of acceptance and use is dependent on trust in implementers. General informants noted that implementers should drink water treated in the same method they are promoting and should recruit support from respected community members—such as religious, political, or social leaders—to gain trust and encourage adoption. Informants also reported 'conspiracy theories' surrounding chlorine tablets, citing examples in which users believed tablets were contraceptives, caused infertility or lack of sex drive, would cause their children to be stunted, or would harm their children and animals. Several informants cited cases in Islamic countries where users believed Christian organizations were trying to poison or 'dumb them down'. While some misconceptions can be resolved by improved education and promotion, most implementers do not feel prepared to address these cultural barriers. One suggestion was that the involvement of sociologists and anthropologists in training may aid in addressing these barriers and improving chlorine tablet acceptance and use.

> "The taste is normally the biggest drawback I think I have heard about [chlorine tablets]."
>
> —WASH Practitioner (General KII)

> "People are just not used to the taste. So, it's not even that the levels were extremely high, people's acceptance of the taste was not there."
>
> —WASH Practitioner (Taste and Odor KII)

> "Or the perception that chlorination or chlorinated water is associated with adverse health outcomes, which are not really fact based, but they're definitely opinions and perceptions that people hold."
>
> —WASH Practitioner (General KII)

> "On the other hand, folks who are accustomed to drinking chlorinated water will only drink chlorinated water and will be suspicious of water that does not have an obvious taste and odor to it."
>
> —WASH Practitioner (General KII)

> "Encourage your own staff to drink the water themselves. If they will not drink it, there is no way that we can expect or should we expect other people to."
>
> —WASH Practitioner (General KII)

#### 3.1.5. Chlorine Tablet Dosage

Informants noted that dosage guidelines from the World Health Organization (WHO) for urban contexts have been adapted by the United States Centers for Disease Control and Prevention (CDC) and the Sphere Project to form differing recommendations for emergencies without additional evidence. Standards generally suggest that water should maintain an FCR of 0.2–0.5 mg/L in stable settings and 0.5–1.0 mg/L when there is a risk of outbreaks at the point of consumption [5,11,12]. One informant noted these summary guidelines based on the type of setting are an apparent simplification for ease of use. Current values were understood by informants to be a "rule of thumb" rather than based on evidence of effectiveness or taste and odor rejection thresholds. Taste and odor informants noted that guidelines should be designed primarily to ensure microbiological safety of the water but also to avoid taste and odor rejection. However, because initial water quality is highly variable and the risk of rejection is often high in emergencies, informants cited a need for detailed, evidence-based recommendations for effective dosages that consider factors such as water quantity and quality.

All informants commented on the variety of dosages of chlorine tablets available, with the 67 mg tablet (20 L), 33 mg tablet (10 L), 17 mg tablet (1 gallon), and the 8.5 mg tablet (2 L) most commonly mentioned. Dosages are doubled in most emergency settings or for high turbidity water. Informants noted that despite the variety in production, only a few dosages are typically available for any given organization and compose the majority of tablets on the market. Informants noted that dosage requirements may change from day to day, and that responders are conservative when dosing water to ensure microbiological safety at the point of consumption. This sometimes results in water with a higher FCR than necessary.

Informants noted that the benefit of tablet variety is the ability to meet varying needs of populations with an applicable dose for the relevant container size. All informants noted that this variety can cause issues, especially if different tablets are provided over time or by different agencies, causing confusion among users, implementers, and distributors. Despite differences in dose, tablets are similar in appearance and some implementers do not fully understand the differences, leading to inadequate knowledge transfer to users. For example, after the 2010 Haiti earthquake, tablets already in circulation from development programs were confused with those of different dosages distributed for emergency response. Users often did not remember or fully understand the differences between tablets, leading to both over- and under-dosing. Informants noted that rejection may often occur when water is dosed at levels much higher than required for adequate disinfection, whether through error or because of conservative dosing schemes.

> "Well then of course it's possible to tailor. You could have a photograph or a picture of container X with a picture of one, two, or three tablets underneath it."
>
> —WASH Practitioner (General KII)

> "It confuses partners. It confuses then what's messaged. It confuses, you know, what you accompany. Do you give a 10 L jerrican? Do you give a 20 L jerrican? How much water are we supposed to be treating with this dosage?"
>
> —WASH Practitioner (General KII)

"Currently, the guidelines are based on no evidence."

—WASH Practitioner (Taste and Odor KII)

#### 3.1.6. Intervention Effectiveness

While informants were positive about the use of chlorine tablets as a short-term intervention in emergencies, most expressed skepticism about the ability to be effective in the longer-term. The two most commonly voiced concerns were those about dosing confusion and taste and odor rejection. One informant felt that the confusion surrounding the variety of tablet doses compromised intervention effectiveness. While other informants agreed that this issue was a challenging one, they did not believe it prevented programs from being successful overall. However, they did feel that confusion leading to over- or under-dosing could cause chlorine in water to cross the taste and odor threshold and result in rejection or provide users with false confidence in inadequately treated water, respectively. Informants discussed that if the water is not safe at the point of consumption, the intervention is no longer effective.

"I don't think [having different dosages available] compromised my decision to use them, it impacts the planning on how I would use it and how I'm going to coordinate. Obviously, it's an effective treatment method."

—WASH Practitioner (General KII)

"In the end it's an ethical issue. Essentially at the end of the day there may be people who think that they're treating their water and they're not."

—WASH Practitioner (General KII)

#### 3.1.7. Recommendations for Distributors and Implementers

Recommendations centered on two themes: avoiding taste and odor rejection and avoiding confusion over proper dosing. Taste and odor informants suggested that chlorine taste and odor rejection can be limited by establishing communication between users and suppliers, so that users can voice their concerns and suppliers can educate about the benefits of chlorine. Although informants indicated that their organizations attempt this, effectiveness varies by organization and often in the early stages of an intervention, the immediate need to begin distribution of safe water takes priority over these conversations. Smaller organizations may lack resources for promotion programs that facilitate communication. Informants agreed that organizations often only considered feedback when complaints or rejection were causing problems, rather than anticipating problems. Informants also recommended treating with lower doses of chlorine closer to the point of consumption, though this can be difficult to monitor to ensure proper use. More advanced technologies could be used so that water is less turbid before chlorination, thereby reducing chlorine demand and the chlorine dose required.

For dosing confusion, several informants indicated a need for involvement from manufacturers in the creation of guidelines specifying when to use chlorine tablets and which doses to provide in given situations. Several informants recommended that fewer doses be available to decrease confusion among users, however, other informants indicated they valued the variety available. To avoid the use of different tablets with the same populations, informants recommended improving information transfer between organizers and implementers, who should be well-trained to assess the situation in the field and select the best tablets for that population. A helpful tool to facilitate this would be the inclusion of the anticipated FCR concentration for the tablet in the specified volume on packaging so that implementers could then adjust dosing based on their assessment of water quality. Another approach is improved intra-organizational coordination, including a set of guidelines that can be implemented uniformly for coordination of chlorine tablet dosing and are based on the needs in each emergency.

> "Community engagement is probably the key. . . . getting people to understand that, okay, the taste might not be what they're used to, but it's a safety issue."
>
> —WASH Researcher (Taste and Odor KII)

> "The main thing is responding to complaints. . . . having a mechanism by which you get this feedback is already a good start."
>
> —WASH Practitioner (Taste and Odor KII)

> "I think what's important from a product perspective is the dosing. So I think there needs to be clear instructions or guidelines as to when different doses would be appropriate in different settings."
>
> —WASH Practitioner (General KII)

> "For the most part, it's just thinking about the coordination issue and trying to get on top of that at the beginning."
>
> —WASH Practitioner (General KII)

### *3.2. Taste and Odor Literature Review*

In addition to the KIIs, we conducted a literature review on one of the most common challenges mentioned by respondents—taste and odor rejection. Water can take on a wide variety of taste and odor properties that make it more or less palatable to users. Taste (governed by the gustatory system) and odor (governed by the olfactory system) combine with other factors such as temperature and mouthfeel to create the overall sensation of flavor [13,14]. Flavor can be difficult to separate into taste and odor, and many chemicals in water are more easily detected as odors than as tastes [15]. The tastes, odors, and mouthfeel of water that produce flavor come from three primary sources: (1) naturally occurring chemical and microbiological properties, (2) chemicals added or removed during treatment, and (3) inputs and reactions occurring during distribution and storage [14]. There is no direct relationship between chlorine water flavor and the safety of water for drinking, however users often interpret water quality based on flavor [14]. There are two components to this judgment: (1) detection of a flavor, and (2) perception of that flavor. Detection is the ability to identify the flavor, while perception is the judgement users make about the water as a result of the flavor [13].

Detection is the physiological ability to sense a property, and experimental studies have demonstrated the ability of users to detect chlorine in water at very low levels. Formal chlorine detection experiments found that users were able to detect chlorine at low levels between 0.1–0.8 mg/L [13,16–19]. Although users typically describe the flavor of chlorine as a taste, detection appears to be driven largely by odor. A study in Dijon, France found that the olfactory system detected chlorine at very low levels (>0.14 mg/L) compared to the gustatory system (3 mg/L) [13]. However, it appears that the level of sensitivity depends somewhat on prior practices and training. For example, French users typically drink water with around 0.3 mg/L FCR or less and are more sensitive to chlorine than users in the United States, where water typically has about 1.0 mg/L FCR [19,20]. Some studies and regulatory bodies utilize panels of people who are trained to determine whether flavors are detectable, while others use lay people, and one study found that participants who were trained were 2–4 times more sensitive to chlorine [16]. Therefore, prior exposure and training appears to make chlorine more detectable. No difference in detection has been observed by sex, but as people age, their ability to detect chlorine is reduced [20,21].

Perception is the interpretation of chlorine detected in the water by a user. Depending on experience, education, and social norms, populations that are able to detect chlorine in water at similar levels may perceive the presence of chlorine very differently. Detection of chlorine in water may indicate to users that something is wrong with the water [22] or that the water is safe [23,24]. Regardless of perception of safety, users may avoid treating water with chlorine because the flavor is

so unpalatable to them [25,26]. A study of the Tz'utujil Maya people in Guatemala found that users educated in water treatment, those with a positive attitude towards water treatment, and those who believed most people treated their water were more accepting of chlorine flavors. However, this study also found that users had come to associate the chlorine taste with disruptions in water supply caused by war and hurricanes and when the taste was associated with these dangerous experiences, it seemed to pose a threat [27].

Overall, the literature suggests that people have the ability to detect chlorine flavors in water at low concentrations, particularly through odor. However, there has been little research to understand the complex behavioral and social factors that form user perception of water, particularly in contexts outside of western water distribution networks. There is little in the existing literature on how users in a wider range of cultural and economic contexts respond to chlorine flavors, particularly when chlorine is newly introduced and in the context of disaster or sudden negative change and deteriorated water quality, as is common in emergencies.

## 4. Discussion

We conducted 14 semi-structured interviews with key informants (9 with a general focus on chlorine tablets, and 5 with a specific focus on taste and odor) including WASH practitioners, academics, and representatives of donor organizations and industry. From these interviews, we conducted an exploratory analysis identifying informant attitudes on themes that may impact program success. We determined that chlorine tablets are regarded as an effective and popular water treatment method; however, informants had concerns surrounding acceptance and use. The two most commonly identified challenges were both social and communication challenges: rejection of water based on concerns about chlorine and chlorine taste and odor, and a lack of clear dosing recommendations that can result in confusion and mis-dosing. Informants recommended that these challenges could be mitigated by increased communication between users and responders including more attentiveness to user preferences, and by improved dosing guidelines and increased intra-agency communication for consistent programming.

Behavioral interventions can be difficult to implement in emergencies [28,29]; however, there is consensus among WASH practitioners and academics that it is typically not enough to provide users with tools for water treatment without appropriate cultural and contextual sensitivity as well as relevant behavior change promotion [30,31]. Informants stated that although they felt that behavior change promotion, user feedback, and consistent monitoring were important for program success, these elements were rarely integrated proactively into chlorine tablet programs. Respondents provided many suggestions of solutions rooted in social and behavioral interventions, including methods of making health benefits salient, drinking water themselves in front of recipient communities, fostering trust, facilitating feedback, and addressing rumors. Social scientists, including behavioral scientists and anthropologists, should be more frequently involved during implementation of chlorine tablet programs to help achieve effective uptake. It is recommended that future research focus on ways in which behavior promotion programs impact effectiveness of chlorine tablet programming, particularly in terms of the impact on taste and odor rejection and dosing confusion.

Informants noted that the biggest contributors to rejection seemed to be avoidance of chlorine due to negative rumors, negative perception, or taste and odor rejection. Taste and odor rejection was an especially large problem when users had not previously been exposed to chlorinated water, however, they also noted that at times users favored water with a chlorine taste and odor, as they associated chlorine with health and safety. Results from the taste and odor literature review align with these perceptions, suggesting that while chlorine can be detected at low levels by most populations, the aversion to taste and odor is more about the perception of chlorine than the physiological ability to detect its presence. In other words, chlorine is rejected when it is not only detected, but is also perceived negatively. Informants cited many instances of rumors and mistrust surrounding chlorine use, and a lack of clarity on the association between chlorine and safe water in many populations. They

emphasized that building trust, accepting user feedback, and correcting misinformation about chlorine were essential to ensure that users drank sufficiently chlorinated water.

For dosing confusion, respondents recommended emphasizing promotion and monitoring programs that teach and support correct and consistent use. Clearer dosing guidelines and improved packaging could reduce confusion, but the primary recommendation was increased inter-organizational coordination of tablet programs. This could include both better guidelines about use of tablets in different contexts, but also a network or process which could be used to easily and quickly generate agreement on a tablet and dosing scheme for a given emergency to prevent inconsistent distribution or messaging. Increased coordination could also facilitate better access to user feedback and encourage increased promotion and monitoring.

This was an exploratory study on informant experiences, and as such we were not able to identify the ways in which various programmatic factors are related to the challenges that were identified. However, the themes and attitudes identified here provide a valuable foundation for further work characterizing these issues. Further research is already in progress to address some of the findings from this study. To address dosing confusion, a working group of 24 emergency responders, researchers, and chlorine industry professionals with experience in chlorine tablet programs was recently formed to gather expert opinions and create a process to provide guidance on the selection of specific size(s) of chlorine tablets which should (non-bindingly) be recommended for distribution in a particular emergency context. Over a series of six calls, a selection process was created based on a series of rapid assessments identifying the level of chlorination required to make water safe to drink, meet local taste and odor acceptability thresholds, and also depending on the availability of tablets. The balance between these factors is expected to be different in each context in which the process is deployed. The result is a guidance document, which includes tools for conducting assessment and guidelines for interpretation and cooperative decision making in the selection of a final tablet(s) appropriate for the context [32]. The process was then field-tested in Cox's Bazar, Bangladesh, where results demonstrated that had the process been used, a smaller dose tablet could have been chosen to effectively treat water while reducing taste and odor concerns [33].

This study had several limitations. All interviews were conducted in English due to resource restrictions, and informants were limited to those who responded positively to efforts to recruit participants and were therefore eager to discuss emergency water treatment programs. Limited prior research on effectiveness of chlorine tablet programs in emergencies was available to guide development of KII guides. Finally, KII methodology is limited to self-reported data by each individual interviewed, and interpretations are subject to personal bias, selective memory, or misattribution. Informants in both sets of KIIs raised the concern of dosing confusion, however, they may have been primed to discuss this issue because many had been recently invited to join or had joined a committee discussing solutions for dosing confusion. Despite these limitations, we feel that informants provided consistent information that yielded new qualitative insights on the challenges and strengths of chlorine tablet programs.

## 5. Conclusions

Chlorine tablets are widely distributed in emergencies and can be a practical and effective short-term intervention to provide safe drinking water. However, concerns can be addressed to make programs more effective, particularly around the social and behavioral issues impacting taste and odor rejection and tablet dosing and distribution confusion. More emphasis is needed on behavior change for chlorine tablet programs in emergencies, along with further guidance on establishing appropriate dosing guidelines and facilitating coordination. Recently, guidance has been developed and trialed to facilitate coordination of tablet dosing recommendations and choice, and further use in new emergencies may help limit dosing confusion. More research is needed to provide solutions to negative taste and odor perception and water rejection. Most of the concerns surrounding taste

and odor are social, not technical, and the emergency water community should engage social and behavioral scientists to develop solutions to facilitate trust and improve acceptance of chlorine.

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