

# Compliance with a boil water advisory after the contamination of a municipal drinking water supply system in Norway

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## ABSTRACT

Boil-water advisories (BWAs) are one of the several methods to prevent the spread of infectious diseases through contaminated water. However, for BWAs to be effective, consumers need to be aware of, understand and comply with the advisories. Although BWAs are a widely used preventive public health measure, compliance with BWAs is rarely examined. In Norway, only one previous study on compliance with BWAs has been conducted. Therefore, we conducted a cross-sectional study to estimate consumers' perception of and compliance with a BWA following a contamination incident at an elevated reservoir in Konnerud (population 10,314), Norway. In total, 2,451 of the 9,312 (26.3%) invited residents responded to the questionnaire. Among the respondents, 97.6% remembered receiving the BWA, of whom 94.6% complied with the advice. Effective compliance with the BWA was thus 92.3%. Only 130 (5.4%) respondents did not comply with the BWA. The main reason for non-compliance was perceived low or no risk of getting sick from the water (34.2%). Our study revealed high awareness of and compliance with the BWA, but the people who did not comply maintained several misconceptions about waterborne infections and transmission. The findings can be used by local health authorities to improve future BWAs.

**Key words** | awareness, boil-water advisory, communication, compliance, drinking water, trust

## HIGHLIGHTS

- We investigated perception and compliance to boil-water advisories (BWAs); it is rarely studied.
- Findings show high BWA compliance and increased trust in water quality following BWA.
- Lack of trust had a negative impact on compliance.
- Non-compliance was associated with misconceptions regarding waterborne infections and transmission.
- Recommendations include having guidelines and rephrasing of BWA to directly tackle misconceptions.

## INTRODUCTION

Access to clean drinking water is essential for human health. However, even in countries with reliable water supply

systems, contaminated drinking water can be a vehicle for pathogens, resulting in cases of gastroenteritis and waterborne outbreaks (MacKenzie *et al.* 1994) or exposure to potentially harmful chemicals (Pieper *et al.* 2018; Hyllestad *et al.* 2020). Despite preventative measures, drinking water can be microbiologically contaminated or inadequately

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disinfected at the raw-water source or during distribution to the consumer (Moreira & Bondelind 2017). Issuing boil-water advisories (BWAs) to consumers is a commonly used measure to prevent waterborne illness in the case of microbiological contamination of drinking water (World Health Organization [WHO] 2011). Boiling effectively kills microbes (World Health Organization 2002) and can prevent gastrointestinal illness among consumers (Cohen & Colford 2017). However, the impact of a BWA strongly depends on consumer awareness of and adherence to this advice. Compliance with BWAs is rarely monitored (Vedachalam *et al.* 2016).

As contamination events can occur in the water supply system at any time, water-safety plans are key in preventing the exposure of consumers (World Health Organization 2004; Davison *et al.* 2005) and have become a widely used approach with reported positive effects (Gunnarsdottir *et al.* 2012). WHO recommends issuing BWAs if water quality is compromised – for example, in cases of disruption of the water supply by an outage, detection of faecal indicator bacteria, failure to disinfect the water or confirmation of a waterborne outbreak (WHO 2011).

In Norway, water-safety planning is a requirement for water suppliers according to the Norwegian Legislation on Drinking Water (Lovdata 2017). Water is an abundant resource in Norway, and it is estimated that each inhabitant uses an average of approximately 180 L of water per day, including roughly 2.4 L for consumption (Statistics Norway 2020). On average, approximately one third of the produced drinking water is lost during distribution due to leakages in the pipelines (Statistics Norway 2020). Occasionally, contamination is detected through routine monitoring for faecal indicator bacteria. The sampling locations are risk-based and often include raw water, treated drinking water and selected locations on the distribution network, such as elevated water reservoirs, inputs to hospitals and consumers at the end of the supply network (Nygård *et al.* 2007; Ercumen *et al.* 2014). While issuing BWAs is included in the routine procedures of many water suppliers, a recent study of BWA practices among water suppliers in Norway revealed discrepancies in the number of BWAs issued and procedures used (Kjørsvik & Hyllestad 2020).

Awareness of gastrointestinal illnesses associated with main breaks and water outages that remain undetected by

faecal indicator bacteria have also led to the implementation of precautionary BWAs as a standard practice in several countries, including Norway (Health Canada 2015; Kjørsvik & Hyllestad 2020). However, an increase in precautionary BWAs in the future has been discussed in the academic community as a potential dilemma, and the WHO has highlighted the potential negative effects of BWAs, including increased consumer anxiety and scepticism regarding the quality of drinking water, and has advised careful consideration before issuing a BWA (Baird 2011; WHO 2011).

On 22 August 2019, a routine water sample taken from an elevated water reservoir located in the Konnerud residential area, part of the drinking water supply system in the Drammen municipality, tested positive for intestinal enterococci. A follow-up sample taken the same day also tested positive for intestinal enterococci. Upon confirmation of the two positive tests, the local health authorities issued a BWA to all the residents of the affected area on 27 August. We conducted a cross-sectional study to examine the perception and compliance by the residents in Konnerud who received the BWA in order to provide recommendations to local health and water authorities regarding the use of BWAs.

## METHODS

### Study site

This study was conducted in Konnerud, a residential area in the Drammen municipality in Viken county. Glitre, a lake bordering Drammen and three adjacent municipalities, serves as the raw-water source. The raw water is processed at the Landfall water treatment facility and temporarily stored in a series of elevated reservoirs before entering the municipal distribution network and ultimately reaching consumers.

### Study design and population

In October 2019, we conducted a cross-sectional study in Konnerud. We invited all residents aged 16–100 years who received the BWA advice on 27 August to participate. All residents were registered as customers of the water

supplier in the Drammen municipality. The water supplier confirmed the names and addresses via the National Registry, using a geographical information system to identify consumers connected to the affected water supply system. The main communication mode for the municipality is SMS text messaging (in addition to voice messages). Residents with mobile phone numbers registered in these systems were included in our study. Multiple phone numbers registered to the same household all received an invitation to participate in the study via SMS text messages.

### Data collection

Data were collected using a web-based questionnaire, which included questions related to respondents' demographic variables (sex, age and education) and compliance with the BWA or the reasons for non-compliance. We used a Likert-type scale for questions concerning the communication, perception of the BWA, and trust and perception of the drinking water and the responsible water supplier. The questionnaire was issued in Norwegian 30 days after the incident. The recipients had 14 days to respond, and a feedback reminder was sent 10 days after the initial inquiry. In addition, we collected data on municipality demographics from Statistics Norway, the national statistics institute of Norway, to compare the respondents to the overall population demographics of the municipality.

### Data analyses

We compared the demographic data from the whole municipality to the data to those reported by the respondents. We described the sex, age and education of the study population. We calculated the proportion of the respondents who remembered receiving the BWA and complied with the advice in order to calculate the effective compliance rate. Using Pearson's chi-squared test and logistic regression, we determined whether there were differences in compliance in terms of the sex, age and education of the participants. Regarding those who did not comply with the BWA, we described the main reasons for non-compliance. Using the Likert scale, we determined the communication methods, perception of the BWA, trust and perception of

the drinking water quality and the responsible water supplier. We compared the level of trust and the perception of participants who complied and those who did not comply with the BWA using logistic regression. All data analyses were done using STATA/SE 16.0.

### Ethical consideration

The study did not require the collection of sensitive information on the study population, and approval from ethical committees was not required. The respondents remained anonymous to the Norwegian Institute of Public Health.

## RESULTS

### Characteristics of the study population

As of 1 January 2019, Konnerud had 10,314 residents, of which 9,312 fit our inclusion criteria (aged 16–100 years) and were sent an invitation to participate in the study. In total, 26.3% (2,451 individuals) responded to the questionnaire.

Most respondents were female (59%) and significantly younger than the male respondents (50 and 53 years, respectively,  $p < 0.001$ ). In the Drammen municipality, the mean age of the population at the time of the study was 47 years, with 50.5% being female.

### Communication, awareness and compliance with the BWA

Among the respondents, 97.6% (2,391) remembered receiving the BWA. The remaining respondents either indicated that they did not receive the advisory (2.0%) or did not recall receiving the advisory (0.5%). Most respondents found the advice 'very easy' or 'easy' to understand (84.9 and 13.4%, respectively). Only a small proportion found the BWA difficult to understand (<1%, 18 people).

Of those who remembered receiving the BWA, 94.6% complied with the advice, resulting in an effective compliance of 92.3% (Table 1). Women were significantly more compliant (97.0%) with the BWA than men (91.1%;

**Table 1** | Effective compliance with the BWA issued 27 August 2019 to residents in Konnerud, Drammen municipality

Health advice	Awareness	Compliance	Effective compliance rate
Boil the water for drinking and food (BWA)	97.6% (2,391/ 2,451)	94.6% (2,261/ 2,391)	92.3% (2,261/ 2,451)

Awareness: respondents remember receiving the BWA. Compliance: respondents remember receiving the advice and complying with the BWA. Effective compliance rate: percentage of respondents who received the BWA multiplied by percentage of respondents who complied.

$p < 0.001$ ). No statistically significant associations were found between compliance and age or education.

Despite being aware of the BWA, 117 (4.9%) respondents did not comply, and 13 (0.5%) did not remember complying. For those who indicated that they did not comply, the reasons for non-compliance can be found in Table 2.

### Perception and trust

The water quality in the Drammen municipality was assessed to be 'good/very good' by 91.4% of the respondents and 'bad/very bad' by <1% (20 people). Most of the participants (88.3%) were 'not worried/not very worried' about contracting disease via tap water, with only 5.1% (127) of the respondents stating they were 'worried/very worried.' In response to the community's ability to handle similar incidents in a safe manner, the majority (91.3%) of the respondents had 'high/very high' confidence and few (1.8%) had 'low/very low' confidence. Following the BWA distribution, 9.2% of the respondents experienced decreased trust in water quality, while the majority (56.1%) reported an increase of trust. The rest stated that the BWA had no

**Table 2** | Reasons for non-compliance with the BWA issued 27 August 2019 to residents in Konnerud, Drammen municipality ( $n = 117$ )

Reason	N	%
Low risk of getting ill	40	34.2
Does not drink a lot of water	37	31.6
Did not remember	24	20.5
Water was clear/clean	14	12.0
Forgot	10	8.6

influence on their trust (33.4%) or that they were uncertain (1.4%). Water quality and confidence in the community's ability to handle the situation were significantly associated with lower compliance (Table 3).

### DISCUSSION

The present study reported on public compliance with a BWA in a high-income country after the confirmation of faecal indicator bacteria in the drinking water supply system. The findings demonstrate overall successful factual communication from the responsible authorities, combined with high levels of awareness of and compliance with the BWA by the consumers. Trust in water suppliers was also satisfactory, and most respondents experienced an increase in trust following the BWA. Whether the BWA is issued as a precautionary advice preceding a planned event or triggered as a result of an acute emergency, awareness of and compliance with the advisory is essential for the advisory to have effect. However, few studies have investigated the relationship between the BWAs and compliance. The latest meta-analysis was published in 2016 and included a total of 11 studies from the United States, the United Kingdom and the Netherlands over a 30-year period

**Table 3** | Compliance with the BWA and the perception of and trust in water quality and the community

Variable	Categories	Compliance (%)	p-value
Water quality	Bad/Very bad	68.4	<0.001
	Neutral	91.8	0.121
	Good/Very good	97.7	Ref
Risk of getting disease from water	Worried/Very worried	91.9	0.158
	Neutral	94.4	0.806
	Not worried/Not very worried	94.8	Ref
Confidence in community	Low/Very low	81.4	<0.001
	Neutral	91.3	0.041
	High/Very high	95.1	Ref
Trust in water quality after the BWA	Decreased	94.3	0.235
	Neutral	93.4	0.296
	Increased	95.3	Ref

Ref: reference category in regression analyses.

(Vedachalam *et al.* 2016). The basis for comparison between studies is therefore limited, but similarities can be observed.

### Awareness and compliance

According to the international meta-analysis of public compliance with BWAs, compliance rates ranged from 36 to 98% (median 76%; Vedachalam *et al.* 2016). In our study, we observed a compliance rate of 94.6% and an effective compliance rate of 92.3%. We believe these positive results are mainly attributable to trust in the responsible authorities that have developed over years as a result of continuous reliability in delivering clean drinking water (Organisation for Economic Co-operation and Development [OECD] 2019). As this was the first BWA issued in many years to our study population, it is also likely that this led to a high level of interest and compliance compared to other contexts where repetitive precautionary BWAs could lead to fatigue and loss of interest from the public (Hrudey *et al.* 2006; Grover 2011).

Differences in the demographic profile, including gender and age, were observed between the respondents and the municipality. Like the studies in the meta-analysis, our study revealed a skewed gender distribution, with the majority being female (59%). If and how this might have influenced our study is unknown, but our study revealed that women were more likely to comply with the BWA than men. The true compliance could, therefore, be lower than estimated by our study. We did not consider the difference in mean age (3 years) to represent a significant impact on the representativeness of the study. The difference in mean age (three years) was not considered to have a significant impact on the representativeness of the study.

Despite being aware of the BWA, a small proportion of the respondents chose not to comply with the recommendations. To improve compliance rates further and minimise potential health risks, it is crucial to understand the reasons for non-compliance. In our study, we found that the main reasons for not complying with the BWA were primarily linked to a low perception of risk. Other reasons given for non-compliance (Table 2) included the water looking clear and the respondent only drinking small amounts of tap water. Although the amount of water consumption and the appearance of the water may provide

indications of the water condition, they are not parameters that consumers can utilise to exclude risk. These misconceptions could be addressed directly in future BWAs to improve BWA compliance.

### Communication

Simple and unambiguous communication is essential when trying to convey a BWA to an audience that includes a range of different sociodemographic groups (WHO 2004). At the same time, it is important to provide information beyond just the BWA in order to uphold trust and create a complete awareness of the situation for the consumers. In our study, the BWA contained short and concise information on the incident, the advice to boil water, and a time frame. An active link to the municipality web page with more detailed information was also included in the BWA. Based on the results from our study, the water supplier in this incident successfully managed to convey the BWA, as indicated by the very low disapproval regarding the content of the BWA. In Norway, recommendations for the wording and content of a BWA do not exist (Kjørsvik & Hyllestad 2020), and the different approaches to BWAs between communities could lead to different interpretations by the consumers – considering the recommendation to be a question of ‘free choice’ or having only advisory (Hyllestad *et al.* 2019).

### Perceived trust

Trust in water quality following BWAs may differ between countries but also within countries. The WHO states that BWAs can have substantial adverse consequences and that frequent and prolonged advisories may decrease compliance (WHO 2004). In our study, more than half of the respondents described increased trust in the water quality following a BWA, one-third of the respondents were unaffected, and a small number of the respondents lost trust. In a similar study conducted in Norway just a year earlier, 79% of the respondents reported an increase in trust, 17% remained unaffected and only 1% experienced diminished trust as a result of the BWA (Hyllestad *et al.* 2019). While both Norwegian studies indicated positive feedback regarding BWAs, there was considerable variation in the proportions

of respondents feeling unaffected or losing trust. One reason for these differences could be that the study by Hyllestad *et al.* was conducted after a precautionary BWA as opposed to the incident in Konnerud, when water contamination was already confirmed. The results of our study also confirmed that the respondents who had less trust in governing authorities were less likely to comply with the BWA. This further emphasises the importance of trust as a key factor in relation to compliance.

### Limitations and bias

One limitation of our study was the relatively low response rate of 26.3%. This was lower than hoped for but not unanticipated as comparable surveys have shown similar results (Jones-Bitton *et al.* 2016; Vedachalam *et al.* 2016; Hyllestad *et al.* 2019). Consequently, non-response bias could exist in our study. However, we have no indication that the non-responders differed significantly from the responders. Nevertheless, the two groups that could be under-represented are the elderly and the non-Norwegian speakers. The fact that the survey was only distributed via text messages may have excluded the few individuals who do not own a mobile phone from participating. This may have contributed to a disproportionate exclusion of mainly the older population as they are more likely to not own a mobile phone and may also feel less comfortable participating in a web-based survey. The survey was not issued in any other language than the native Norwegian, which could exclude people who are not comfortable communicating using the Norwegian language. An ever-increasing number of requests for user-experience feedback on phone applications and websites may also generally discourage survey participation.

To the best of our knowledge, there was no increase in morbidity or mortality during, or immediately after, the incident that triggered the BWA. For many consumers, this incident did not have a direct impact on their health, which may have further contributed to decreased interest in engaging in the survey. People who did not comply with the BWA might also have been less likely to respond to the survey. Desirability bias, whereby the participant selects the response that is most socially desirable or 'correct,'

cannot be excluded, but by anonymising the study, we believe we have minimised the impact of desirability bias.

The relatively short time period between the BWA and our survey may, on the other hand, have contributed positively to the reported compliance rates by reminding the respondents of the incident and reducing potential recall bias.

### CONCLUSIONS

The results of our study on the perception of, and compliance with the BWA in Konnerud demonstrated that the water supplier was highly successful in communicating the BWA in an understandable manner. Albeit a small proportion, non-compliance did exist and was primarily linked to a lack of perceived risk and misconceptions about the transmission of waterborne illness. Based on these findings, we suggest that future BWAs address these issues directly in the advisory by including targeted information about specific risks. To reduce potential confusion among communities regarding BWAs and maintain a high level of trust by the consumers, we also believe that a uniform set of guidelines and regulations concerning BWAs should be considered.

Our study expands the knowledge of a scarcely studied topic in public health. Continued population growth, an aging water supply system and prospects of more extreme weather are all factors that might fatigue the water supply infrastructure in the future and increase the risk of water contamination. An increase in precautionary BWAs and emergency BWAs following more severe contamination incidents should, therefore, be planned for. We recommend continued research and monitoring of compliance with BWAs.

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## DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

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