ORIGINAL ARTICLES

Situation of microbiological contamination in bottled drinking water products and some influencing factors in Hau Giang province in 2020

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ABSTRACT

Background: Bottled drinking water has become popular for consumption by customers. Bottled drinking water with pathogenic microbiological contamination is a public health concern. This study aimed to describe the current situation of microbiological contamination in bottled drinking water products, food safety conditions and some influencing factors in production facilities in Hau Giang province in 2020.

Methods: A cross-sectional study has been conducted in 2020 using quantitative and qualitative methods. The evaluation was carried out at 54 bottled drinking water production facilities, 108 workers/owners and 54 samples collected from facilities for microbiological analysis in the province. In-depth interviews were conducted with local government officials on food safety, two owners of facilities and two workers.

Results: It showed that the proportion of microbiological contamination in bottled drinking water accounted for 18.5%, of which P. aeruginosa contamination was 18.5%; and Coliform contamination was 3.7%; No drinking water samples were contaminated with E. coli. 79.6% of facilities met general food safety conditions. There were several factors affecting the proportion of microbiological contamination of bottled drinking water as follows: Bad compliance with food safety in production for the sake of profit by workers, affecting the quality of products such as trash cans without lids; No sterilization treatment before filling; Non-sterilization in filling room. Non-monitoring of UV lights for replacement; No regular cleaning of water pipes, tanks, and discharge valves; Difficulty in state management of food safety for facilities of bottled drinking water production, such as insufficient manpower, lack of equipment and funding for activities.

Conclusion: The quality of bottled drinking water in Hau Giang province was not good. The important factors affecting the contaminated bottled drinking water products were identified. We recommend that: management agencies should frequently conduct sudden inspections and supervisions of facilities with no ensured food safety and strictly handle according to regulations. Owners of bottled water facilities should voluntarily comply with food safety. This study is particularly concerned with ensuring food safety conditions in the production of bottled drinking water to prevent products from microbiological contamination.

Keywords: *Microbiological contamination; E. coli, Coliform, P. aeruginosa; bottled drinking water; food safety conditions; Hau Giang province.*

INTRODUCTION

Contaminated bottled drinking water is extremely dangerous, because there is the possibility of contamination with some types of pathogenic bacteria, affecting the health and even life, possibly causing infectious diseases of the intestinal tract. According to the Our World in Data (2017), each year, about 1.6 million people die from diarrheal

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diseases, of which a large proportion is due to contaminated food and water (1). The US Agency for Disease Control and Prevention estimates that there are about 76 million cases of food-borne illness per year (about 5,000 deaths) (2). In Sri Lanka, according to the study on bottled drinking water by Sasikaran.S *et al.,* samples of bottled drinking water sold at Jaffna Peninsula were collected for testing of bacteria, among 14/22 samples submitted for testing, 9% were contaminated with *Coliform, E. coli, and fecal Streptococci* (3). The consumption of bottled drinking water in Sri Lanka has increased over the past decade. However, manufacturers' compliance with regulations on bottled water is questionable, raising concerns about the quality of bottled water with conducted microbiological analysis within 01 to 03, 03 to 06, 06 to 09, and 09 to 12 months after the date of production. The results showed that 63% of brands tested exceeded the allowable level of the Sri Lanka Standards Institution (SLSI) for the assumed total *Coliforms* (TC) (<10 CFU per 100 mL), while 97% of brands exceeded the level allowed by WHO. 30% of brands exceeded limits for assumed fecal *Coliforms* (FC) (0 CFU per 100 mL as permitted by WHO, SLSI, and Sri Lanka Ministry of Health requirements) (4).

In Vietnam, the use of bottled drinking water is chosen by consumers for drinking at homes, at workplaces, in outdoor activities and gradually replaces rainwater and boiled water. The above studies show that bottled drinking water products are polluted, do not ensure the quality as advertised on the media, as well as product publication (5). Besides, current regulations on bottled drinking water by countries are different. We have carried out this study to determine the quality of bottled drinking water in terms of microbiological criteria, evaluate food safety conditions according to current regulations (6,7,8) and determine factors affecting the quality of bottled drinking water. The results will provide scientific information to evaluate the risks of bottled drinking water to public health and support decisions on risk management to control the production and treatment of bottled drinking water. Quality data on the microbiological aspects of bottled drinking water from Hau Giang province, Vietnam can provide useful understandings for developing appropriate actions and programs on microbiological risk management of bottled drinking water products in Vietnam and other countries with similar contexts.

METHODS

Study design: A cross-sectional study was conducted from January to September 2020 using both quantitative and qualitative methods.

The study subject: Facilities of bottled drinking water production, 500ml bottled drinking water samples produced at production facilities and owners of facilities and direct producers at facilities of bottled drinking water in Hau Giang province. 02 local government officials on food safety; 02 owners and 02 workers who directly involved in the production process (including 02 facilities with failed water quality samples and 02 facilities with passed water quality samples).

Sample size and sampling

54 facilities of bottled drinking water production in Hau Giang province had records of registered administrative procedures for food safety conditions managed at the Food Safety and Hygiene Department. All owners and workers of 54 facilities (108 people)

participated in the survey and interview. Among 54 facilities (one sample per facility), a total of 54 samples were collected and conducted microbiological analysis *(E. coli, Coliform and P. aeruginosa)*. In-depth interview participants were selected purposefully on their relevance to the research questions and their role in ensuring the quality of bottled drinking water. In total, two local government officials on food safety, two facility owners and two employees (01 facility owner and 01 employee have a failed sample; 01 facility owner and 01 employee with passed sample) were invited to participate in in-depth interviews.

Table 1. Three criteria to evaluate the quality of bottled drinking water samples according to Vietnamese standards QCVN 6-1: 2010/BYT

- Microbiological criteria for the first test

First test			
No.	**Name of criterion**	**Amount of sample**	**Requirement**
1	Heat resistant *E.coli* or *Coliform*	1x250 ml	Not detected
2	Total *Coliform*	1x250 ml	If the number of bacteria (spores)> 01 and <02, the second test is conducted.
3	*Pseudomonas aeruginosa*	1x250 ml	If the number of bacteria (spores)> 02, reject it

- Microbiological criteria for the second test

No.	**Name of criterion**	**Maximum allowed limit (in 01 ml of product)**			
		a [1)]	**b [2)]**	**c [3)]**	**d [4)]**
1	Total *Coliform*	4	1	0	2
2	*Pseudomonas aeruginosa*	4	1	0	2

*Remarks:

+ a [1)]: Number of sample units collected from the lot to be tested

+ b [2)]: Maximum number of sample units with a result between c and d, total number of samples with results between c and d exceeding b is failed.

+ c [3)]: The limit at which the results do not exceed this level is passed, and if the results exceed this level, it may be passed or failed.

+ d [4)]: The maximum limit that no samples are allowed to exceed it.

Data collection

A researcher investigated, collected 100% of facilities, observed their conditions and chosen to tick the prepared checklist. This researcher asked each question directly to employees, observed their practices, and interviewed them in 20-25 minutes. During the sampling process, an investigator under the Department with a practice certificate

collected samples to avoid errors that can affect the microbiological quality of bottled drinking water and collected samples of bottled drinking water. All samples of bottled drinking water were then tested as soon as possible, within 48 hours, and such samples were delivered to NhoNho Technology Company in Can Tho city - a unit certified for food safety testing by the Ministry of Health. Analyzes included quantitative analysis of *Total Coliforms, Escherichia coli,* and *Pseudomonas aeruginosa.* Test method for *Coliform* and *Escherichia coli* followed ISO 9308-1:2014/Amd.1:2016 and test method for *Pseudomonas aeruginosa* was ISO 16266:2006. The quality of bottled water was assessed according to QCVN 6-1:2010/BYT (9). The quality of data was controlled in the field by the principal investigator for this study. The principal investigator of this study recorded in-depth interviews.

Data analysis and statistical methods

Descriptive statistics were undertaken; entered data and conducted the analysis using SPSS 20 software to evaluate the quality of the facilities' bottled drinking water samples and food safety conditions. Qualitative data were analyzed according to identified themes.

Ethical considerations

The head of this study was approved by the Ethics Council of the Hanoi University of Public Health under Decision No. 114/2020/YTCC-HD3 dated 25/3/2020 on approving ethical issues of biomedical research. All human subjects in the study were required for their consent before data collection and all had the right to withdraw from the study at any time without any threat or disadvantage.

RESULTS

General information of facilities

Of the 108 direct producers participating in the study, direct producers with qualification of secondary education account for nearly 42%, followed by those with qualification of high education and higher level (higher education, college, intermediate level) nearly 29% and 20%, respectively, and those with primary education accounts for 10%. The ratio of male owners of facilities of bottled drinking water production accounted for 60%, the rest were female owners. 100% of owners were the ones directly engaged in bottled drinking water production. The number of employees working at facilities of bottled drinking water production was mostly two people, accounted for 74.1% and there was no facility with six or more people. Operating time of such facilities was relatively long, facilities from 05 years or more accounted for over 48.1%; facilities from 03 - <05 years accounted for nearly 23%; facilities from 01 - <02 years accounted for nearly 15%; facilities from 02 <03 years accounted for nearly 10% and facilities <01 year accounted for 5.6%.

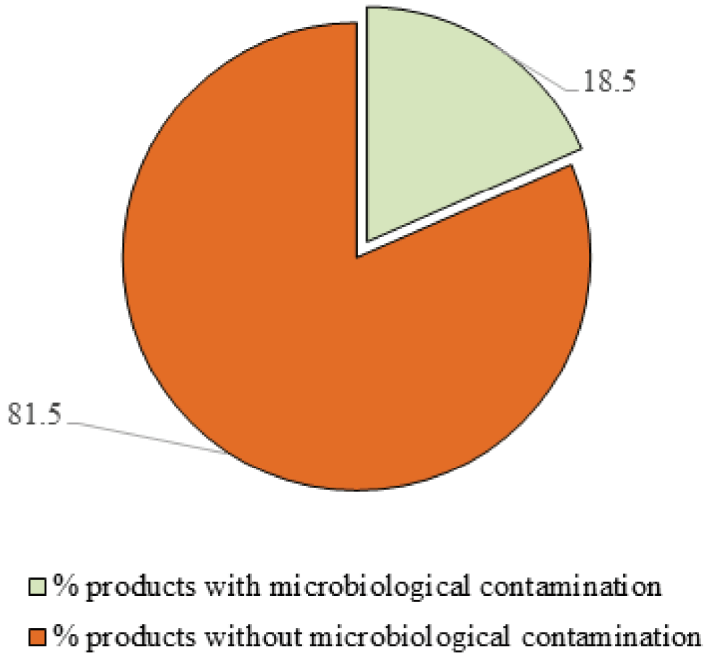

Figure 1. Overall quality evaluation of microbiological criteria

Figure 1 shows that there were 18.5% of bottled drinking water products contaminated with microorganisms, failing to meet the requirements of microbiological criteria according to QCVN 6-1: 2010/BYT.

Table 2. Quality evaluation according to each microbiological criterion

No.	Name of microbiological criteria	Bottled drinking water contaminated with microorganisms		Bottled drinking water not contaminated with microorganism	
		Frequency	Percentage %	Frequency	Percentage %
1	*E.coli*	0	0	54	100
2	*Coliforms*	2	3.7	52	96.3
3	*Pseudomonas aeruginosa*	10	18.5	44	81.5

The results of the survey on microbiological criteria of 54 samples of bottled drinking water showed that the percentage of bottled drinking water products that did not meet the requirements of each microbiological criterion according to QCVN 6-1: 2010/ BYT, from high to low levels were: *P. aeruginosa* (18.5%), *Coliform* (3.7%) and no products contaminated with *E. coli*. Out of 10 bottled drinking water products contaminated with microorganisms, all were contaminated with *P. aeruginosa*, of which there were 02 samples contaminated with *Coliform*.

Food safety conditions of facilities

Table 3. Requirements on factory conditions

Item	Passed		Failed	
	Frequency (n= 54)	Percentage (%)	Frequency (n= 54)	Percentage (%)
One-direction design from bottle washing stage to the finished product of bottle drinking water	51	94.4	3	5.6
Trash cans with lids	43	79.6	11	20.4
General food safety conditions	43	79.6	11	20.4

All facilities had closed filling rooms, separate from other areas; toilets arranged separately from the production area; room of labor protective dressing; closed, well-ventilated, non-stagnant waste treatment system, etc.; 03 facilities (5.6%) had production areas that did not follow one-direction principles; However, in terms of facilities with closed and covered trash cans, only 79.6% of facilities met requirements. General conditions of food safety of bottled drinking water production facilities reached 79.6%.

To limit the risk of microbiological contamination of products, facilities must equip trash cans with lids and carry out a daily waste collection to prevent cross-contamination of bottled drinking water products by flies, mosquitoes, mice, cockroaches, etc. However, the results of interviews showed that facilities had trash cans but no lid, direct producers only emptied the rubbish when these trash cans were full, not at the end of the day of production. This was one of the factors affecting bottled drinking water contaminated with microorganisms.

"For trash cans do not have lids. I leave them outside of the production area. At the end of the day, I empty the rubbish." (In-depth interview with an owner of a passed facility).

"....Trash cans do not have lids, I only put the rubbish two to three times a week, the rubbish is packed in nylon bags, nothing dirty." (In-depth interview with an owner of a failed facility).

Once a facility was certified as eligible for food safety, after a period of operation, the facility must take action to maintain its compliance with the general food safety requirements as its initial conditions, however, some facilities did not maintain it due to being afraid of the cost and spending time, as a result, such facilities were degraded and damaged; besides, some facilities maintaining good food safety practices. General conditions of food safety was another factor affecting bottled drinking water contaminated with microorganisms.

"All facilities of bottled drinking water in the province have been appraised and certified for the facility to meet the requirements of food safety, so at the time of issuance of the certificate, basic conditions are met". (In-depth interview with the Head of Inspection under the Department).

"We don't know how to maintain food safety, just do it, whatever the inspection team reminds us of, we will fix it". (In-depth interview with an employee of a failed facility).

"It also works normally to produce." (In-depth interview with an owner of a failed facility).

"It also works well and cleanly, we just maintain it". (In-depth interview with an owner of a passed facility).

Correct food safety practices of direct producers

Table 4. Evaluation of sterilization of containers and personal hygiene when filling

Item	Passed		Failed	
	Frequency (n=108)	Percentage (%)	Frequency (n=108)	Percentage (%)
The bottles were washed and dried before being put into the water filling room	52	48,1	56	51.9
Covers and caps of bottles were sterilized before filling	42	77,8	12	22.2
Covers of bottles were rinsed with finished water	107	99.1	1	0.9
Workers did not have long nails, painted nail, wear jewelry	87	80.6	21	19.4
Workers, when filling, used special clothing, masks and gloves as prescribed	33	30.6	75	69.4
When entering the filling room, the door was closed, without talking and going out and in continuously.	82	75.9	26	24.1

The aseptic process of containers for bottled drinking water was also a very important stage in the production process, as this was one of the essential factors to ensure food safety for bottled drinking water. If this stage was not done carefully, there was a risk of unsafe products of bottled drinking water. Table 5 shows that only about 48% of the bottles were washed and dried before being put into the filling room for filling. Covers and caps of bottles were not put into the filling room to disinfect before the filling is 22.2%. The food safety conditions of the filling room were very important, affecting the quality of bottled drinking water in terms of microbiological criteria. After entering the filling room, practices of closed doors, no talking, no going out or going in, only 75.9% of facilities met this requirement. 19.4% of workers had long nails; 69.4% of employees did wear labor protection clothing (special clothing, masks, gloves) when filling according to regulations.

"... For rinsing bottles, if not cleaned, thoroughly dried, just roughly rinsing with water and then discharge, the entire bottles are not rinsed; In case of not disinfecting such bottles, contamination will occur. Moreover, other reasons including not using good RO with high pressure of about 13 kg and not replacing new ones regularly, below 24 months. Also, UV lights are important, so it is necessary to monitor the usage time, from tanks of raw water to tanks of semi-finished products to finished products, I

equipped with UV lights; in addition, poor personal hygiene, no pipes, and water tank rinsed cleanly, etc. are reasons causing contamination of bottled drinking water". (In-depth interview with an owner of a passed facility).

"I know but not very well, I do it cleanly and clean the tools, wash my hands before working." (In-depth interview with an owner of a failed facility).

The facilities knew well the process of bottled drinking water production, from rinsing, drying bottles, putting them in the sterilized filling room, rinsing with finished water, filling with water into bottles to produce finished products according to the one-direction principle. However, some facilities' owners thought that new bottles purchased by them were unused and clean, so there was no need to wash, dry, rinse with finished water, and sometimes did not disinfect the cover of bottles.

"For bottled after collection, I clean and rinse them, I have a bottle washing machine, then hung them up to dry, then put into the filling room, turn on the lights to disinfect and then rinse and fill them with water, close lids tightly and bring them out to label".

For bottles: *"Bring bottled into the filling room, wash with finished water, then use UV lights, then fill with water and cover them, and bring them out to label. I arrange such bottles in a plastic basket and use lights for sterilization."* (In-depth interview with an owner of a passed facility).

"For bottles after collection, I spray and wash cleanly, then hang them up to dry, then bring them to the filling room, to disinfect and then rinse with water, cover and bring them out to label."

For bottles: "*Because they are newly purchased bottles, they are brought into the filling room to fill with water and cover, then labeled and packed in blocks." We do not clean bottles and dry them before bringing them into the filling room, because they are new ones, we do not clean them. I put all of them into the filling room and turn on the lights for sterilization. However, sometimes we do not have time, so we do not disinfect bottles, only rinse with the finished water and then fill."* (In-depth interview with an owner of a failed facility).

For filling rooms, all facilities must be equipped with ultraviolet lights for disinfection and follow regulations when entering the filling room. The facilities did good jobs of opening the UV light to sterilize the space in the room before conduct filling, closing the door, taking the water out through the side door of the room; however, some facilities skip the sterilization of bottles/ jars with ultraviolet light and do not close the door or go in and out the room continuously when filling, so the opening of UV light for sterilization before filling did not guarantee the absolute sterility of the filling room and also increased the risk of microbiological contamination of the product.

"...we always close the door before conduct filling. We also turn on ultraviolet light for sterilization about 30 minutes before working. We know that the sterilization light is turned on to kill microorganisms in the air in the filling room, so the room must be kept closed to ensure the filling room is free of microorganisms contaminants in the product. So there must be 2 people, 1 person inside and the other outside the room". "Turn on the light to sterilize bottles before filling water." (In-depth interview with the owner of the passed facility), (In-depth

interview with the employee of the passed facility).

"... because the glass filling room was too hot, they cannot close the door, so we open the door; Open the door of the filling room to bring the filled bottles out through the main door of the filling room, since the filling room is small, bottles are brought out for sealing and labeling and shrink wrapping... turn on the ultraviolet light for 30 minutes before conduct filling... Turn on the sterilization light in the filling room to kill microorganisms in the room... Sometimes the time is too urgent, we need to fill quickly to deliver water to customers... turn on the sterilization light to sterilize all bottles at the same time. However, sometimes we do not make it in time, so we do not disinfect the bottles, just rinse the water and then conduct filling. "Turn on the sterilization light to sterilize all bottles at the same time, not separate each bottle." (In-depth interview with the owner of the failed facility), (In-depth interview with the employee of the failed facility).

Through interviews with the facilities, it was found that the compliance with regulations in the filling room was still limited, after sterilization of the room, the room must be closed during the filling process, the opening of the door to go in and out continuously must be limited to ensure that filling room after turning the ultraviolet light is sterile, even if the facilities were equipped with ultraviolet light for disinfection, some facilities still have microbiological contamination in their bottled water products because their bottles were not disinfected before filling.

Table 5. Evaluation of sterile practices of direct producers

Content	Correct	
	Frequency (n= 108)	Percentage (%)
Wash hands with antibacterial water then wash with clean and dry hands before conducting production	93	86.1
Start the Ozone generator, turn on the UV light for ≥ 30 minutes before conducting production	108	100
Garbage is collected daily	39	36.1
Clean equipment: tanks, pipes, discharge valves > once a month	79	73.1
There are books to monitor the use of UV light in water and replace the light	82	75.9

According to results observed for 108 direct producers, still, 13.9% did not wash their hands with antibacterial water, then rinsed with clean water and dried hands before entering the filling room. Before entering the filling room for production, most had operated an ozone treatment system and turned on the ultraviolet light for 15-30 minutes to 100% sterilize, ensuring the filling room was sterile. Only 36.1% of garbage was collected and disposed of every day, this was also a potential factor causing cross-contamination,

making it unsafe for bottled drinking water. The time interval between times where the direct producer cleans the equipment less than one month accounts for 73.1% and 75.9% of the workers had a monitoring book to replace the UV light according to regulations. This was the last stage to destroy all remaining microorganisms or re-infection source after raw water was treated through filtration systems especially through RO membrane and stored in the finished water tank, so if the UV light in the water was not replaced timely, the light was damaged or was still operated but has expired as required by the manufacturer, the lamp would no longer function to kill microorganisms in the finished water.

To limit the risk of microbiological contamination of products, facilities must conduct personal hygiene before production, perform labor protection, regularly clean and replace if tools serving the production were damaged; and daily collect garbage. However, interviews showed that the direct producers often forgot or did not care about hand washing before production, often did not wear labor protection because they thought that it was inconvenient and difficult to produce. Garbage was usually collected and brought out when the trash was full, not at the end of the production day.

"Before working, we sanitize hands, wash hands, wear face masks, slippers, and disinfect the filling room. Replace and clean production equipment. Turn on the UV light for about half an hour, then enter the room after turn it off, wash hands with soap, clean water, dry hands, wear boots, masks, and protection gears. Take out all garbage at the end of the day." (In-depth interview with the owner of the passed facilities).

"We do not were a separate shirt in the filling room because it is very hot and uncomfortable, do not wear gloves because it is difficult to do and easy to be torn. We wash our hands, but sometimes we forget because of we were too hurry." (In-depth interview with the employee of the passed facilities).

"... we do personal hygiene such as washing our hands, wearing protective gear, and masks. We know the regulations on hand-washing but sometimes we forget, and we often do not wear protective gear, masks in the filling room because it is too hot and uncomfortable, and wearing gloves is difficult to work. We wear slippers in the filling room to avoid the corrosion of feet due to water." (In-depth interview with the owner of the failed facilities).

"... about 3-4 days or 1 week at the latest, we clean the hose with a pressure hose and clean water. The residue is dirty, if we clean the pipe once a year, it will be too dirty, our pipe is dirty for about a week, I know because they sealed pipes with glue, so they cannot clean. Learning from experience, I connect the pipes with an elbow, do not glue, so it is easy to remove when cleaning." (In-depth interview with the owner of the failed facilities).

"The pipeline is closed, so it is very difficult to open for cleaning due to glue, requiring stop of production to do it. We usually cut out and replace the new pipeline." (In-depth interview with the owner of the failed facilities).

Facility interviews shown that the majority of facilities did not care about the water pipelines and water tanks located outside the filling room area, the owner thought the closed pipe was not dirty, so they did not regularly clean. Factors of cleaning equipment more than once a month and monitoring UV light in water affected microbiological contamination of products.

In addition, through in-depth interviews with local government officials on food safety, with a thin force of managers, sometimes there were limitations in operations, especially the organization of inspection teams "*The staff of the inspection department is very few, not enough to perform the task and must often coordinate with other specialized departments in the Sub-Department to perform.*" (In-depth interview with the head of the inspection department)*;* Funding for food activities has decreased over the years. The budget for the targeted program of population health granted by the central government for food safety has decreased and the support budget of the province is low; The lack of equipment for inspection, the supervision of sampling and testing to assess the risk of pollution also had difficulty, in the province, no food sample testing laboratory meets ISO 17025 standards, so samples must be sent to neighboring provinces, this limited food safety management in the province. "*The equipment is also relatively good, but Hau Giang province has not had a food sample testing laboratory that meets ISO 17025, so samples must be sent to Can Tho for testing, funding for food safety is mainly from the program of Central Population Health. Support from the local budget is very low. Every year, the funding for food safety decreases, the next year is lower than the previous year."* (In-depth interview with the head of the inspection department); In the province, most of the facilities were small, so the organization of inspection and examination at facilities was mainly propaganda, reminding to raise the awareness of observing the law on food safety for facilities, handling of violations using a fine was limited, leading to the facilities' negligence on the quality of the product to meets the standards on bottled drinking water. "*We often remind and guide facilities to overcome shortcomings to do better in the future."* (In-depth interview with the head of the inspection department). Therefore, there were a number of challenges facing local authorities and bottled drinking water manufacturers to ensure the food safety of bottled drinking water products in Hau Giang Province.

DISCUSSION

This study evaluated the quality of bottled drinking water products and the influencing factors at production facilities in Hau Giang Province in 2020 using a cross-sectional approach with both quantitative and qualitative methods. The food safety evaluation carried out in all 54 bottled drinking water production facilities in the province and 54 samples of bottled drinking water taken shows that 10 samples were contaminated with microorganisms, which accounted for 18.5%. The main causes were poor compliance of facility owners and employees with safety practices in the production of bottled drinking water. In-depth interviews showed that there were still limitations and difficulties in management.

Bottled drinking water is used directly without any further treatment, so the microbiological quality of bottled drinking water is very important to prevent food-borne diseases. The relationship between the general conditions of facilities that do not ensure food safety, and incorrect practices in the production of bottled water highlights the significance of studies on the hygienic quality of bottled drinking water. Several studies on the microbiological quality of bottled drinking water have been documented worldwide (10, 11). However, in Vietnam, to our knowledge, data on microbiological contamination of bottled drinking water is still very limited. There

are both similarities and differences between findings from this study and international research evidence. A study was conducted in Sri Lanka by Sasikaran.S *et al.* on bottled drinking water, the results of bacteria, in 14/22 samples submitted for testing, 9% were infected with *Coliform bacteria, E. coli, and Streptococci Feacal* (3). In Dar es Salaum in 2007, Tanzanie Gabriel. R.K. analyzed 130 bottles of bottled water, the results show that 92% of samples is contaminated with heterotrophic bacteria, total *Coliform bacteria* and *fecal Coliform* bacteria in food are 4.6% and 3.6% (11). Therefore, results from studies in countries demonstrate that bottled drinking water samples can cause a public health risk due to the presence of indicator microorganisms such as coliforms in feces and *E. coli*. In bottled drinking water contaminated with harmful microorganisms, especially multidrug-resistant bacteria such as *E. coli, Salmonella,* and *Staphylococci,* which can cause infections and pose a serious threat to global public health. The results of this study were lower than those reported in the study of Cao Thi Diem Thuy (2016) that the ratio of microbiological contamination of bottled drinking water in Ben Tre province was 40.9% (12); not much lower than the study of Nguyen Dieu (2018) on bottled drinking water in Tay Ninh province which found that the infection ratio was 23.0% (13). The ratio of microbiological contamination was higher than that of Vu Kim Yen's study (2016) evaluating the status of implementing some food safety regulations of bottled drinking water facilities in Bac Ninh province, the results showed that only 7.0% of the finished water samples failed, contaminated with all 5 microbiological criteria (14). *E. coli* was not detected in any bottled drinking water samples collected in Hau Giang province and showed that *E. coli* in bottled drinking water samples at the time of the study is relatively safe for users.

Production facilities with no-lid trash, regulations of filling room, sterilization bottles, equipment cleaning more than once a month, monitoring of UV light in water, daily garbage collection, and general food safety conditions of the bottled drinking water facilities affected the microbiological contamination of bottled drinking water.

Strengths and limitations of this study: To our knowledge, this was the 1st study evaluating the quality of bottled drinking water *(Coliform, E. coli, Pseudomonas aeruginosa)* at the production facilities and influencing factors in Hau Giang province and this was also one of a few studies in Vietnam evaluating the microbiological quality of bottled drinking water products. Our study contributes to existing knowledge showing potential public health risks associated with microbiological contamination in bottled drinking water. This article complements the existing documents describing pathogen contamination in bottled water drinking products in developing countries. The evidence from this study can provide useful insights for developing appropriate food safety policy responses and programs in both Vietnam and other similar institutions around the world to minimize health risks to consumers of bottled drinking water.

Although this study has reported certain important results, some methodological limitations of this study must be considered. First, due to the limited budget, all the microbiological indicators could not be evaluated according to QCVN 6-1: 2010/ BYT. Secondly, raw water samples were not tested, only 01 sample of finished water/ facility was taken to evaluate the quality of bottled drinking water products. Third, the

test results of bottled drinking water were only valid on tested samples and products on the same day and production lot. Last but not least, although consumption of microbiologically contaminated bottled water drinking products is associated with various health effects, this study was unable to evaluate health effects between microbiologically contaminated bottled drinking water products. Therefore, we recommend that future studies focus more on this aspect to fully evaluate the health risks associated with microorganisms in bottled drinking water products.

CONCLUSIONS

In Hau Giang province, the ratio of microbiological contamination in bottled drinking water products was quite high (18.5%). The main pollutants were hygienic indicator bacteria like *Coliform* (3.7%) and pathogenic bacteria like *Pseudomonas aeruginosa* (18.5%). No *E. coli* was detected in 54 bottled drinking water samples. Bottled drinking water facilities did not fully satisfy all the prescribed food safety conditions, only 79.6% meet the general food safety conditions. Factors affecting microbiological contamination of bottled drinking water products have been identified including: Trash without lid; bottle shells were not sterilized before filling; Bottled drinking water fillers did not comply with regulations in the filling room; did not clean tank equipment, water pipeline, and discharge valves more than once a month; did not monitor the usage time to replace the UV light. The presence of *Coliform* and *Pseudomonas aeruginosa* in the bottled drinking water product showed that the consumption of bottled drinking water in Hau Giang province can be potentially dangerous. Employees with poor manufacturing practices were major challenges that many bottled drinking water production facilities in Hau Giang province have to overcome. This was a fairly comprehensive study, not only investigating the microbiological quality of bottled drinking water, but also the sanitary conditions of the equipment, the personal hygiene of the direct producers, the conditions of food safety of bottled drinking water production facilities in Hau Giang province and related factors. The results of the current study provide important data demonstrating the factors that can cause contamination of bottled drinking water.

RECOMMENDATIONS

This study shows that the food safety management of bottled drinking water in production facilities is very important and urgent. To ensure the food safety management of bottled drinking water, not only the facilities' documentation and procedures must be fully followed, but the general food safety conditions of the manufacturing process and manufacturing practices must be maintained to ensure the safety of bottled drinking water products from employees directly producing bottled drinking water. Regular inspection and supervision of the facilities' food safety conditions and quality of bottled drinking water products should be carried out in Hau Giang province, as well as other regions of Vietnam, the health sector needs to monitor these factors and have relevant policies to promote action on social determinants of health. Further studies should be conducted to assess the public health issues in relation to current bottled drinking water in Vietnam.

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Conflict of interest

The authors of this study claim no conflict of interest concerning research, copyright, and publication of this manuscript.

REFERENCES

1. Our World in Data 2017. Diarheal diseases. Accessed 1 June 2021 at: https://ourworldindata.org/diarrheal-diseases.
2. Nguyen Dinh Chau, Barbara Tomaszewska, in Bottled and Packaged Water, 2019, Vol. 4: The Science of Beverages 2019, Pages 1-38.
3. S Sasikaran, K Sritharan, S Balakumar, V Arasaratnam (2012), "Physical, chemical and microbial analysis of bottled drinking water", *Ceylon Medical Journal,* 57, pp. 111-48.
4. AnuraHerath, CharmalieAbayasekara, RohanaChandrajith, N. K. B. Adikaram (2012) "Temporal variation of microbiological and chemical quality of noncarbonated bottled drinking water sold in Sri Lanka".
5. Food Safety Department 2013, Report on food safety inspection and inspection results at the collective kitchen facility, bottled drinking water in the first 6 months of 2013 and Report on inspection results on public food safety of 12 key provinces and cities.
6. Vietnamese Government. Decree No. 155/2018/ND-CP dated November 12, 2018 on amendments to some articles related to business conditions under State management of the Ministry of Health. 2018, pages 1-4.
7. National Assembly (2010), *Law on Food Safety*, Law No.: 55/2010/QH12 dated July 16, 2010 of the National Assembly, pages 1-4.
8. Vietnamese Government (2018), *Decree No. 115/2018/ND - CP dated September 4, 2018 of the Government on penalties for administrative violations against regulations on food safety, pages 7-10.*
9. Ministry of Health (2010), Vietnam Regulation 6-1: 2010/BYT, National technical regulation for natural mineral water and bottled drinking water, pages 3-6.
10. Cristobal C, Marcela S, Celida M, Bruce K. (2008), "Drinking water microbiological survey of the Northwestern State of Sinaloa, Mexico", *Journal of Water and Health,* 6(1), pp. 125-129.
11. Gabriel R.K. (2007), "The health- related microbiological quality of bottled drinking water sold in Dar es Salaam, Tanzania", Journal of Water and Health, 5(1), pp. 179-185.
12. Cao Thi Diem Thuy (2016), *"The ratio of microbiological contamination of bottled drinking water and some factors related to conditions to ensure food safety and hygiene at bottled drinking water facilities in Ben Tre province",* Journal of Nutrition and FoodVolume 12 (Issue 6 (1)), pages 362-364.
13. Nguyen Dieu (2018), *Current situation and some factors related to microbiological contamination in bottled drinking water of production facilities in Tay Ninh Province in 2018,* Grassroots level project of Tay Ninh Province, pages 33-48.
14. Vu Kim Yen (2016), *The implementation situation of some regulations on food hygiene and safety of bottled drinkings water production facilities in Bac Ninh Province in 2016,* Master Thesis of Public Health, Hanoi Univeristy of Public Health, pages 78.