Training and Auditing Material Effectiveness for Good Manufacturing Practices and Critical Control Points of Drinking Water Production Plants in Cambodia

Leab Kong, Wanphen Wimonpeerapattana, Visith Chavasit* and Juntima Photi

Institute of Nutrition, Mahidol University, Salaya, Phuttamonthon, Nakhon Pathom 73170

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Abstract

The major public health problem in Cambodia is inaccessibility of safe drinking water; people therefore must rely on bottled drinking water, especially the 20-liter pack size. Consequently, Cambodian officers must increase their knowledge on production processes and hazard control. In this study, the training and auditing materials were prepared based on the Codex Alimentarius guideline and related researches. The materials were then translated into Cambodian, and evaluated for its effectiveness in order to be used for monitoring the quality and safety of Cambodian drinking water. A two-day lecture was conducted, attended by about 50 participants who were pre-tested for their basic knowledge. For each part of the lecture, a post-test was conducted. After the lecture session was completed, 16 plants were audited by an expert and the trainees. Effectiveness of the training material was evaluated based on performance in the post-test and auditing. Results revealed that post-test scores were significantly higher ($p \leq 0.05$) than those of the pre-test for all parts. Scores from 39 out of 73 audits of the trainees were not significantly different from those of the expert. The auditing performance was significantly correlated with post-test score, trainee affiliation, location of the affiliation, and the GMP status of the plant ($p \leq 0.05$). Information on the post-test score and auditing performance indicated that the passing score for the post-test should be 60 %. The training and auditing materials were thus effective in improving trainee knowledge, which should capable them on monitoring quality and safety of drinking water in future.

Keywords: Cambodia; drinking water; safety; training; auditing

1. Introduction

Adequate water intake is essential for maintaining a healthy life (Montgomery, 2002). Accessibility to safe drinking water is a United Nations Sustainable Development Goal (SDG 6) that member countries need to achieve by 2030 (United Nation, 2016). Unsafe water can directly affect a population's quality of life, since it can

*Corresponding author: vchavasit@gmail.com
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cause acute and chronic diseases. Similar to other developing countries, at least 66 % of the Cambodian population does not have access to safe drinking water sources (Brown *et al*., 2008). Acute illnesses due to unclean water consumption are found frequently in Cambodia. In 2018, for example, consumption of pesticide-contaminated water caused 10 deaths and 140 hospitalizations in Cambodia's Kratie province (Phnompenhpost, 2018).

One of the government's major responsibilities is to ensure that adequate and safe water is accessible and affordable by people of all socioeconomic classes. While bottled drinking water can be a source of safe water, many drinking water producers in Cambodia lack sufficient knowledge for producing it, even though during the dry season most of the Cambodian people must rely on commercially bottled drinking water (White *et al*, 2013). Under such a situation, the role of the government is quite significant in monitoring the quality of bottled drinking water and the manufacturing practices of production plants. Efficient education for officers and producers in industrial processes and the identification of potential hazards is one important strategy that must be performed in parallel with, or prior to, law enforcement. By understanding good manufacturing practices and specific critical control points, inspection and monitoring processes can be more efficient and beneficial to industries, especially in terms of improving their production and quality control systems (FAO and WHO, 2003).

The Codex Alimentarius (CODEX) provides a code of hygienic practice for bottled/packaged drinking waters other than natural mineral waters (namely, CAC/RCP 48-2001) for member countries to use as guideline for monitoring the quality and safety of drinking water within their country contexts (Codex Alimentarius, 2001). In addition, certain researches that had been performed on good manufacturing practices and critical control for bottled drinking water production in many countries are widely available (Zuane, 1990; Institute of Food Science and Technology, 1991; Bryan, 1992; FAO-WHO, 1997; Chavasit *et al*., 2003; Saskatchewan Ministry of Environment, 2003; Nestle Waters, 2014). As being suggested by the United Nations Food and Agriculture Organization (FAO) and the World Health Organization (WHO), the most efficient way to develop a modern regulatory framework that can satisfy both national needs and meet the demands of the SPS agreement, TBT agreement, and trading partners is to use the CODEX standards and the experiences of other countries for tailoring the information, concepts, and requirements to national contexts (FAO and WHO, 2003). In this study, Cambodia as a UN country member was taking full advantages of the CODEX standards as well as experiences in food safety and quality of countries on developing training material for improving the technical skills of officers in drinking water production. The effectiveness of the training and auditing materials were as then evaluated by written examinations and auditing results.

2. Materials and methods

2.1 Training and auditing materials

The training material that consisted of lecture material and an auditing checklist was prepared by using The CODEX on code of hygienic practice for bottled/packaged drinking waters other than natural mineral waters (namely, CAC/RCP 48-2001), which mainly emphasized on general concepts of good manufacturing practices. The additional information concerning critical control points of the small- and medium- scale bottled drinking water plants from research articles were also included in the training material (Zuane, 1990; Institute of Food Science and Technology, 1991; Bryan, 1992; FAO-WHO, 1997; Chavasit *et al.*, 2003; Saskatchewan Ministry of Environment, 2003; Nestle Waters, 2014). The content of the training material as well as auditing checklist were approved by an expert in bottled water production from the Institute of Nutrition, Mahidol University, Thailand, and then translated into Cambodian.

2.1.1 Lecture session materials and testing

The developed lecture materials included presentation slides and test questions. Slide content was divided into three sections: (i) raw water sources and treatment, (ii) production and quality control processes, and (iii) packaging and cleaning. To assess trainee knowledge, pre- and post-tests were used containing the same questions. The questions were multiple choices, with four answer choices and one correct answer. The number of questions for parts (i), (ii), and (iii) were 10, 17, and 15, respectively, with a total score of 42. The scope, contents and choices of the questions were approved by the mentioned expert.

2.1.2 Auditing checklist

The developed auditing checklist for bottled water production consisted of 9 sections, i.e., (i) location and production buildings, (ii) manufacturing tools, machinery, and equipment manufactu-ring, (iii) water resource, water quality adjustment, and standard quality control, (iv) container, (v) cleaning agents and disinfectants, (vi) packaging, (vii) sanitation, (viii) workers' health and hygiene, (ix) records and reporting.

The checklist content was based on the content of the lecture session including the GMP concept as well as pre-hazard analysis and critical control points (pre-HACCP), in which each check could be interpreted quantitatively into a point (based on score x weight). The weight for scoring the pre-HACCP points was higher than for those of the GMP.

2.2 Lecture session

Using the developed training materials, a two-day lecture was conducted for 50 officers from central and provincial offices of Cambodia's Ministry of Industry and Handicraft (MIH) and Ministry of Health. The study's expert performed the lecture in English and the study's researcher translated it into Cambodian. Before the lecture, participants were pre-tested for basic knowledge using examination questions that included all three slide content sections. A post-test was performed right after the lecture and after each section was finished. The times allowed for the pre- and post-tests of sections 1, 2, and 3 were 15, 20, and 20 minutes, respectively. Answers to the questions that were most correct and least correct in the pre-and post-tests were recorded.

2.3 Plant selection and auditing

Based on the MIH database, at least 660 bottled drinking water producers were operating in Cambodia at the time of the study. Of these, 16 premises were audited for location and source of water, namely:

2.3.1 location: Capital Phnom Penh, Siem Reap, Banteay MeanChey, and Prey Veng provinces.

2.3.2 water source: Ground, surface, and tap.

The selected production plants were audited by the expert and the trained participants, which were the officers from central and provincial offices. Each audit consisted of at least 5 trainees. The rest of the auditors joining the audit in each province were the trained officers of such province.

2.4 Effectiveness evaluation of the training and auditing materials

Effectiveness of the training and auditing materials were evaluated by using 2 criteria which were (i) the performance in the post-test after the lecture had finished and (ii) the performance during the production plant audit.

2.5 Statistical analysis

Statistical analyses were performed using the SPSS (version 18) software application. Pre- and post-test scores for each participant in the lecture session were analyzed for significant difference ($p \leq 0.05$) by using either the paired t-test or Wilcoxon signed rank test depending on data distribution. The performance during the production plant audit was evaluated by comparing the auditing scores of the expert and to those of the trainees to determine any significant differences ($p \leq 0.05$) by using either the independent t-test or Mann Whitney u test depending on data distribution. The correlation between the post-test scores and the probability of having a non-significant difference (considered as a higher p-value) of the auditing comparative scores of the trainees and the expert was evaluated using linear regression. Spearman's correlation coefficient was also used due to data abnormality (Daniel and Cross, 2013).

2.6 Ethical consideration

The Ministry of Industry and Handicraft, Cambodia, approved this study and provided ethical clearance. As there were two data collection steps (i.e., pre- and post-tests during the lecture session and the production plant audit), two different written informed consent and necessary information forms for the study were prepared. Participants and bottled water producers were clearly informed about the purpose and procedure of the study in detail prior to data collection. Information about participants and producers was kept confidential, and they were free to withdraw at any time during the study period.

3. Results and discussions

3.1 Pre-and post-tests results

Fifty-three trainees consented to and joined the lecture session, the majority of which were male. Of these, 40 trainees (75 %) completed the pre- and post-tests for all three lecture sessions. The trainees came from four job responsibility areas, all of which had missions dealing with water production plants. Most of the trainees were department heads and officers affiliated with the Ministry of Industry and Handicraft (MIH), which monitors the quality and safety of commercial drinking water (Table 1). Among these MIH officers, 60 % were from provincial MIH offices. Under the Cambodian governmental system, officers from the SME unit and provincial offices are responsible for certifying and monitoring the GMP of bottled drinking water plants and the quality of drinking water. A total of 73 records were obtained from auditing the 16 water plants, of which two-thirds were completed by male trainees.

This study's results show that the scores of the post-test were significantly higher ($p \leq 0.05$) than those of the pre-test for all lecture session sections (Table 2). In terms of question comparison, the number of correct answers for each question was also significantly higher after

Table 1 Profile of the trainees that attended lecture and joint auditing sessions

Lecture session		Auditing session	
Profile of the trainees	Number of trainee (person)	Profile of the trainees (Number of trainees)	Number of audit (time)
Gender		Gender	
Male	40 (88.9 %)	Male (12)	49 (67.1 %)
Female	5 (11.1 %)	Female (2)	24 (32.9 %)
Rank		Rank	
Vice general director	3 (6.7 %)	Department head (7)	49 (67.1 %)
Department head	23 (51.1 %)	Deputy department head (1)	2 (2.7 %)
Deputy department head	5 (11.1 %)	Officer (6)	22 (30.2 %)
Officer	14 (33.1 %)		
Affiliations		Affiliations	
Central office of MIH	13 (28.9 %)	Central office of MIH (5)	23 (31.5 %)
Provincial offices of MIH	25 (55.6 %)	Provincial offices of MIH (7)	26 (35.6 %)
SME unit of MIH	4 (8.9 %)	SME unit of MIH (2)	24 (32.9 %)
Ministry of health	3 (6.7 %)		
Location of the affiliations		Location of the affiliations	
Central	18 (40.0 %)	Central (7)	47 (64.4 %)
Provincial	27 (60.0 %)	Provincial (7)	26 (35.6 %)

Table 2 Efficiency evaluation of the lecture session by comparing scores as well as percentages of the correct answer in the pre- and post-tests

Basis of evaluation					
Part (full score)	Scores of the tests				
	Test	N	Mean	SD	p-value
1 (10 points)	Pre	45	3.58	1.47	0.0000
	post	45	5.67	1.72	
2 (17 points)	Pre	40	6.03	2.91	0.0000
	Post	40	9.50	3.23	
3 (15 points)	Pre	40	6.35	2.12	0.0000
	Post	40	8.40	2.60	
Part (full score)	Percentage of the correct answers				
	Test	N	Mean	SD	p-value
1 (10 points)	Pre	10	35.50	17.56	0.0007
	post	10	57.20	18.04	
2 (17 points)	Pre	17	37.65	14.74	0.0014
	Post	17	57.12	17.33	
3 (15 points)	Pre	15	37.60	23.33	0.0000
	Post	15	56.67	23.65	

the lecture session. The post-test scores improved by 2 to 52 % after attending the lecture. Among the 42 questions, the scores of up to 38 questions improved, though the post-test scores were only approximately 60 % of the total scores. Consequently, after the lecture session, the trainees showed knowledge improvement in most aspects. From our observations, the contents of four questions from parts (i) raw water sources and treatment and (iii) packaging and cleaning had more correct answers in the pre-test than in the post-test. These pre-test questions might have been answered by "educated guesses". However, the same questions in the post-test results might have been answered with uncertainty on their last guesses (Luetsch and Burrows, 2016).

3.2 Comparative scores

Due to limitations in time and budget, not every trainee who attended the lecture session could audit the same number of plants. After visiting 16 factories in the four provinces and using the auditing checklist, 73 checklists were completed and the scores of each trainee at each premise were compared with the scores of the study's expert to determine any significant differences ($p \leq 0.05$). Thirty-nine out of 73 comparisons showed no statistically significant difference ($p \leq 0.05$) between the expert and trainees, which was quite acceptable in the participants who did not have limited background on drinking water production. Under the assumption that five relevant factors (i.e., factory's GMP status, post-test score, affiliation, location, and trainee's rank in the government) might affect trainee performance during the audit, the correlation between the probabilities of having non-significant differences in comparative scores between the expert and the trainees with those factors were evaluated. Such probability was represented by the p-value from statistical analysis of the comparison between the auditing scores of each trainee and the expert, wherein the higher p-value means the better the trainee's performance (less difference from the expert). Four out of these five factors significantly correlated with the probabilities of having non-significant differences in comparative scores between the expert and the trainees as expected.

Figure 1A indicates that the probability of non-significant difference from the expert tended to increase in the trainees who earned more post-test scores, which could result from the continuum of understanding and development of analytical skills from the lecture session. There were also significant positive correlations between probability of non-significant difference from the expert and the affiliations as well as the locations of such affiliations (Figure 1B, 1C). Those who belonged to the SME unit of the MIH performed better than those from the other two units which, in fact, worked more on production plant monitoring (Figure 1B). In this study, the trainees who were working with the SME of MIH joined in the most audits (12 times/person) with the expert, while the ones from the other units (4 times/person) could not do so.

Figure 1C also indicates that the trainees who worked in the central office tended to perform better than the ones who worked in the provinces, possibly due to the greater availability of and accessibility to knowledge in the capital. Moreover, central level officers belonged to the local Phnom Penh to the local Phnom Penh municipality and should have more opportunity for information exploration. In

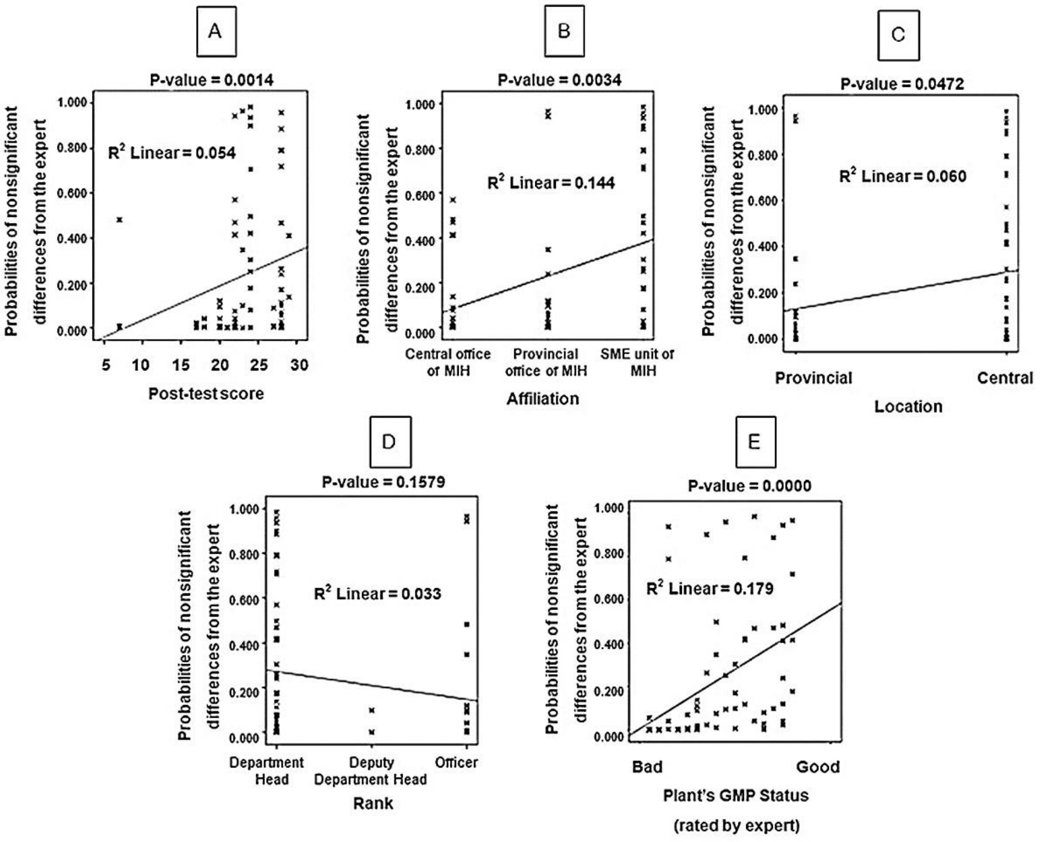
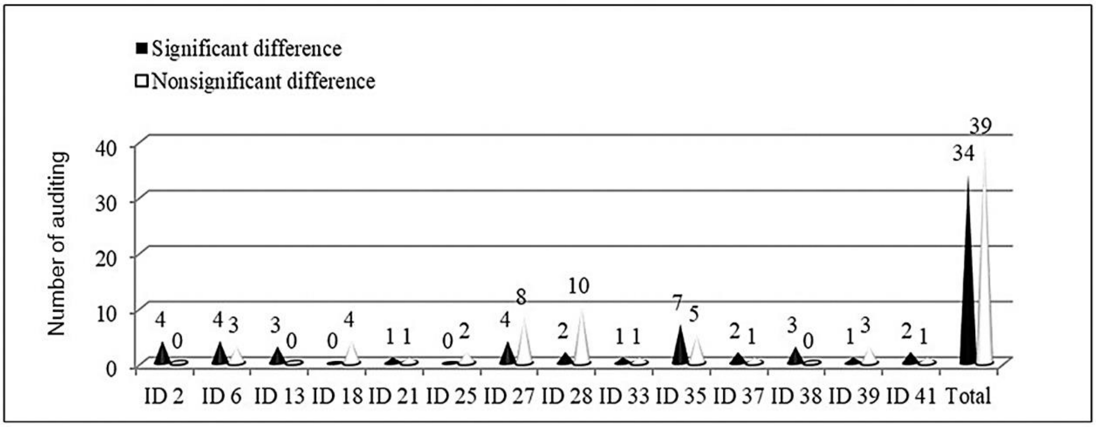


Figure 1 Trends of the correlations between the probabilities of nonsignificant differences from the expert with certain factors



ID 2	ID 6	ID 13	ID 18	ID 21	ID 25	ID 27	ID 28	ID 33	ID 35	ID 37	ID 38	ID 39	ID 41	ID
6	5	4	7	5	7	6	6	6	7	5	8	9	7	Part 1-Post score
6	14	9	11	10	11	12	11	13	7	15	6	6	-	Part 2-Post score
5	1	8	10	7	11	10	7	9	8	7	4	4	-	Part 3-Post score
40%	**48%**	**50%**	**67%**	**52%**	**69%**	**67%**	**57%**	**67%**	**52%**	**64%**	**43%**	**45%**	**17%**	**% of total questions**

Figure 2 Numbers of auditings of each trainee (identified as an ID number) which were significantly and non-significantly different from the results of the expert as compared with the post-test score.

addition, central MIH office personnel must provide knowledge transfer and on-site training on a regular basis for Cambodian officers, especially those working in rural settlements. There was no significant correlation ($p \leq 0.05$) between the probability of non-significant difference from the expert and the ranks of the trainees since most of their responsibilities were similar at the operational level (Figure 1D). The GMP status of the production plant also affected the auditing performance of the trainees. Figure 1E indicates that trainees tended to perform better on a plant that had better GMP status (better scores from the expert). Judgments on perfect aspects were normally easier for inexperienced trainees to make than those judgments that required greater evaluation.

Figure 2 shows the correlation between each trainee's total post-test score with his/her auditing result that were statistically compared with the expert's. Most trainees who did better in the auditing (earned more non-significant number) had achieved at least 60 % of the post-test score. Since this training material is the first to be introduced in Cambodia, the MIH should consider making 60 % as the passing score for this test. An officer who can pass the test with this score should be more capable in monitoring the quality and safety of bottled drinking water. Descriptions of auditing checklist alone without training and experience were inadequate to improve the auditing capabilities of officers.

4. Conclusion

The training program used in this study, consisting of a two-day lecture session and 16 production plant audits, could significantly improve knowledge on bottled water production among responsible Cambodian officers. Moreover, lecture knowledge was found to be a supportive factor for an efficient audit. However, since all of the trainees had very limited background on GMP, the two-day lecture period might need to be extended for the participants who were from the provinces and had no industrial experience. Since the materials used in this study proved to be effective, Cambodian ministries should use it as a basis to further develop appropriate and practical tools for monitoring the quality and safety of drinking water in the future.

5. Acknowledgement

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