Mitigation of water related zoonotic diseases on small-scale integrated farms in Vietnam.

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ABSTRACT

The goals of this study were to 1) assess basic microbial and other quality indicators of drinking and domestic water and 2) identify factors associated with *E. coli* contamination of drinking and domestic water on 600 small-scale integrated (SSI) farms in the provinces of Thai Binh and An Giang in Vietnam. The cross-sectional study relied on questionnaires and on-farm water samples analyzed using standard methods from the Vietnam national protocol for water quality testing. Our results showed that SSI farmers frequently used water of poor quality contaminated with *E. coli* for domestic purposes. In Thai Binh for example, well water had a mean *E. coli* count of 356.5 cfu/100 mls. There were significant differences in the frequencies of use and the levels of *E. coli* contamination regarding water for domestic purposes between the two provinces. Analysis of associated factors revealed that socioeconomic status of farmers and their perceptions of risk factors for water related zoonotic disease (WRZD) transmission were significantly associated with *E. coli* contamination of domestic water. These findings would be informative in the course of formulation of water related interventions and policies, particularly for improving farmer awareness of risk factors for WRZD transmission and improvement of SSI farm water quality in general. Further research should explore farmers' strategies to mitigate WRZD transmission and factors that may influence those strategies.

Key words: *E. coli*, agricultural policy, farm management, public health, Vietnam

INTRODUCTION

Most diseases transmitted to humans through water are water-related zoonotic diseases (WRZD)[1] including salmonellosis and colibacillosis (Ford and Colwell, 1996) as well as highly pathogenic avian influenza (HPAI). The latter has been a particular problem in the Red River and Mekong River Deltas of Vietnam where epidemic waves of HPAI took place between 2003 and 2005 (Gilbert *et al.*, 2008). Early outbreaks during the 2003-5 HPAI epidemic in Vietnam were thought to be associated with bodies of water on farms (Morris and Jackson, 2005).

We refer to small-scale integrated (SSI) farms as those that are small in land base (5 acres or less), raise small numbers of livestock such as pigs or chickens, raise some fish, and grow some combination of crops such as rice and vegetables. SSI farms in Vietnam are managed around the concept of nutrient recycling; animal waste is fed to fish, animal and fish waste is used as fertilizer on crops, and cash crops also serve as a source of feed for livestock. This model has been used successfully in Vietnam and other parts of Southeast Asia for perhaps thousands of years (Devendra and Thomas, 2002). It is only recently with the emergence of HPAI that the suggestion has arisen that this form of mixed farming where animal species live in close proximity and where their waste is circulated in water may be an environment under which there is a heightened risk of emerging infectious disease (Gilbert *et al.*, 2008; Nguyen *et al.*, 2011; Pfeiffer *et al.*, 2009).

The Vietnamese Ministry of Agriculture estimates that more than 70% of Vietnamese SSI farmers use contaminated water, have no access to hygienic latrines, and have limited awareness of water quality or environmental sanitation (MoC and MARD, 2000). Although there is concern regarding the risk of emerging infectious diseases, that risk can be mitigated with the use of good farm management practices including reduction of the release of pathogens into agricultural runoff (Hooda *et al.*, 2000). Despite these concerns, the inappropriate use of water for domestic purposes and the consequences to the health of SSI farmers and their animals have not been well studied. Part of the problem is good understanding of the status of water (*e.g.*, availability and basic water quality) and on-farm water management. This includes water quality on farms, water sources and

[1] In our research, we used the WHO definition of WRZD as diseases in humans that are spread from animals and are related to water such as Highly Pathogenic Avian Influenza, some parasites, or diseases caused by a range of bacteria (*e.g.*, pathogenic strains of *E. coli*) (WHO, 2004). Criteria for determining WRZD include: 1) the pathogen must spend part of its life cycle within one or more animal species; 2) it is probable or conceivable that some life stage of the pathogen will enter water; and 3) transmission of the pathogen from animals to humans must be through a water related route (Moe, 2004).

uses, farmers' awareness of risk factors of water quality, and water use with respect to microbial infection (Dinh *et al.*, 2006; Trang *et al.*, 2007). With respect to testing of water sources, the WHO recommends pH, turbidity, and the presence of coliform bacteria such as *E. coli* as the key microbial and related indicators of rural water quality (WHO, 2012).

This study focuses on socio-economic characteristics of SSI farmers and identifiable factors associated with mitigation of contamination of domestic water on SSI farms. We hypothesize that: 1) the sources and frequency of use of domestic water are different among SSI farmers in Thai Binh and An Giang; 2) SSI farms in the two provinces are faced with low quality domestic water; and 3) socioeconomic status of SSI farmers and their perceptions of risk factors for WRZD transmission are associated with the microbial content of their water used for domestic purposes.

METHODS

With assistance from our partners at the Hanoi School of Public Health and the Water Resources University, we identified SSI farmers in the provinces of Thai Binh and An Giang, provinces located in the centre of the Mekong River Delta and the Red River Delta where waves of HPAI epidemics were focused (Hoang, 2006; Rushton, McLeod, and Lubroth, 2006). From 20 communes we randomly selected 600 SSI farms to participate in the field data collection. A two-stage cluster sampling method was used to select target commune clusters and farm households in each cluster to participate in the study.

Using questionnaires, in-depth interview, and focus group discussion, we collected data from SSI farmers indicating socioeconomic characteristics, livestock production characteristics, and perceptions of risk factors for WRZD focusing on HPAI, coliform bacteria, and parasites (*e.g.*, perceived threat of HPAI to their health and wellbeing). For assessment of microbial and related water quality we followed the Vietnamese national technical regulations on domestic water quality to assess basic indicators of quality of on-farm water (MoH, 2009) and WHO recommendations for assessing the basic indicators of rural water quality (WHO, 2011). More specifically, we collected a 200ml sample of domestic water at each farm. Domestic water was defined as "water used for domestic purposes [such as bathing] but not for drinking or processing food" (MoH, 2009).

Collection, storage, and transportation of water samples followed Vietnam national guidelines on water quality sampling (TCVN 6663, 2011). Both participating national microbiological laboratories sent technical teams to the participating farms to collect two replicates of water samples (200mls each). Water was tested within 6-8 hours of sampling for presence of *E. coli*, pH, and turbidity. For assessing *E. coli* contamination in domestic water, we used the membrane filtration (MF) method. Number of *E. coli* colony forming units (cfu) in 100mls of water was calculated using a standard formula[2].

As well as descriptive summary statistics and t-test of significant differences, we used probit regression analysis to model and test the relationship between presence of E. coli in drinking water sourced from rain or wells, demographic factors, socioeconomic factors, farmers' perceptions of on-farm water quality, related mitigation strategies, and risk factors for WRZD transmission.

RESULTS

Sources of water and frequencies of use

SSI farmers participating in the study in both provinces depended on multiple sources of water for both drinking and domestic purposes (Table 1). In Thai Binh, rain water (196 = 65%) and/or drilled wells (231 = 77%) were most frequently used for drinking water; drilled wells (251 = 84%) and/or river water (251 = 84%) were most frequently used for domestic water. In An Giang, river water (297 = 99%) and/or piped water (243 = 81%) were most frequently used for drinking water; river water (288 = 96%) and/or rain water (267 = 89%) were most frequently used for domestic water.

Microbial and related on-farm water quality

There were slight differences between the pH levels of drinking and domestic water between the two provinces. The mean turbidity levels in these sources of water in An Giang were two to three times greater than in Thai Binh (Tables 2 and 3). Pond water and river water used for domestic purposes in both Thai Binh and An Giang had much greater mean numbers of *E. coli* cfu compared to well water. Drinking water from wells in An Giang had the greatest number of *E. coli* (107.1 cfu) whereas rain water in Thai Binh had the greatest number of *E. coli* (61.8 cfu) for that province.

[2] C (cfu in V mls) = (A ×N) / B; where C = number of *E. coli* cfu confirmed in 100mls water; A = number of presumptive *E. coli* cfu positive with Indole test; B = number of presumptive *E. coli* cfu transferred for further incubation in tryptone soy agar (TSA) medium; N = number of presumptive *E. coli* cfu on filtered incubated membranes with lactose TTC agar medium; and V = volume of filtered sample water.

Table 4 shows the number of positive results for well-plate tests of presence of *E. coli* in drinking and domestic water. River and rain water used for drinking in An Giang were most likely to test positive for presence of *E. coli* while drinking water from well and rain sources were most likely to test positive from farms in Thai Bing Province.

Farmers' characteristics and perceptions of risk factors for WRZDs transmission

Tables 5 to 7 provide summary statistics of farmers' demographic and socioeconomic characteristics and perceptions of risk factors for WRZD transmission that were used as independent variables in modelling factors that we hypothesized were associated with microbial quality of on-farm water. More precisely, on-farm water quality may be associated with demographic factors (*e.g.*, age), socioeconomic status (*e.g.*, years of attending school), and SSI farmers' perceived risk factors of WRZD transmission (*e.g.*, farmers' perceptions of water quality).

Table 8 shows probit regression results for the presence of *E. coli* in rain and in well water (the dependent binary variable) using explanatory variables capturing demographics, socioeconomic characteristics, perceived risk of WRZD, and mitigation strategies to prevent WRZD. These preliminary results indicated that numbers of chickens on farm, years of farming experience, gender of decision maker, self-evaluation of management ability, and perception of risk of contracting HPAI from water were significant predictors of presence of *E. coli* in rain and well water. The sign of predictor variables was not always consistent between rain and well water but differences could be explained (see discussion). Of numerous candidate regressions using various intuitive combinations of independent variables, several resulted in mitigation strategies and presence of fish being significant predictors of the presence of *E. coli*. However, we could not fit acceptable models with sufficiently high concordance (i.e., substantially better than chance) that included these variables for both rainwater and well water. Work on improving these models is continuing.

DISCUSSION

Sources and frequency of use of on-farm water for domestic purposes

The farmers in our study in Thai Binh and An Giang Provinces of Vietnam depended on various sources of water for drinking and domestic purposes. This result is consistent with other reports on sources of water used in rural areas in Vietnam. These sources are river/stream/canal, pond/lake, rainwater collection, piped water, hand dug wells, drilled wells, and bottled water (MoC and MARD, 2000; MoH, 2009). Farm observations (visits) and in-depth interviews with the farmers in the study supported this result. However, the frequencies of using these sources of water for various purposes were different between the two provinces. For example, drilled well water was the most frequently used water source for domestic purposes in Thai Binh while An Giang farmers relied more on river water for domestic purposes. In addition, given the limited supply of not naturally occurring on-farm water (e.g., piped or pumped from municipal sources), it is understandable that rain water was generally a popular source of drinking and domestic water. It requires limited technology to collect and store and is available for most of the year. Similarly for Thai Binh, drilled wells are a popular source of water although the cost of installation and maintenance may be a barrier. In An Giang where incomes are lower, drilled wells were not a popular option; river or canal water was the most popular option. The fact that no single option for water source seemed to dominate in either province indicates to us that farmers simply do not view any single source as reliable year round. This was confirmed in interviews and small group forums.

The differences between the two provinces in frequencies of use of all water sources for domestic purposes were significant, which confirmed the first hypothesis of this research. The hypothesis indicates that frequencies of use of water sources for domestic purposes are different between farmers in Thai Binh and An Giang. For that reason as well as our observations regarding reliability of source, such differences need to be given careful consideration when designing water related interventions and policies. For example, subsidizing drilling of wells may not be successful where it does not consider annual availability of well water or annual maintenance costs of the well.

Low quality of on-farm water for domestic purposes

WHO recommends that *E. coli* be used as an indicator organism to assess the microbial safety of rural water (WHO and OECD, 2003b) and that drinking and domestic water should be free from *E. coli*. There are four main reasons to use *E. coli* as an indicator organism. First, it is not practical to conduct isolations of all pathogens. Second, pathogens from human and animal faeces pose the greatest danger to public health and detecting faecal contamination in water is important for public health safety. Third, methods of assessing *E. coli* are simpler, more available, and more affordable when compared to those of other pathogens. Fourth, *E. coli* is a more specific indicator of faecal contamination compared to other members of the total coliform group. The quality of water for drinking and domestic purpose on our study SSI farms based not only on E. coli but also based on pH and turbidity was low when compared to basic indicators of water quality established and recommended by the Ministry of Health, Government of Vietnam. Levels of pH and turbidity in water have been shown to influence the microbial quality of water (WHO and OECD, 2003); greater levels of turbidity are associated with increased likelihood of water contaminated with pathogenic bacteria, suggesting water collection and storage containers should be considerably lower on our study farms. The significant presence of *E. coli* in both drinking and domestic water on our study farms indicates probable contamination with faeces from livestock and is a warning sign for the possible presence of other pathogens in the water. Farm visits and answers to questionnaires confirmed wide variations in understanding and application of basic water hygiene practices such as covering water storage containers, preventing access by poultry, removing rubber boots when entering domestic buildings, and hand washing before meals.

The mean pH level of on-farm domestic water met the national pH standards for domestic water. However, the mean turbidity and *E. coli* levels in the sources of on-farm domestic water were much greater than those indicated in the Vietnam national standards. Moreover, the mean level of *E. coli* cfu in river water used for domestic purposes in Thai Binh was almost four times greater than that in An Giang. This difference may be one of the reasons why farmers in Thai Binh use river water frequently for domestic purposes and almost never for drinking water. Meanwhile, farmers in An Giang appeared to use river water frequently for both drinking water and for domestic purposes. The microbial qualities of water for domestic purposes were significantly lower than the national standards of water quality and were significantly different between the two provinces. This difference and the low microbial quality of water on-farm needs to be considered when designing interventions and/or further research about on-farm water.

Associated factors of on-farm domestic water quality

Farms headed by men (male farmers were primarily responsible for livestock production) tended to have greater contamination of river water used for domestic purposes with *E. coli* compared to farms that were headed by women. Furthermore, having more pigs and an occupation other than farming and perceived increased susceptibility to parasites from using untreated river water for domestic purposes tended to increase the *E. coli* contamination of river water used for domestic purposes. Farmers who attended more years of schooling, had greater perceived susceptibility to HPAI from using untreated domestic water, and were satisfied with their current sources of domestic water tended to have greater levels of *E. coli* contamination in pond water used for domestic purposes. The sign of the significant predictors in our probit model was not always consistent. For example, having chickens on farm was a positive predictor of the likelihood to test positive for *E. coli* in rainwater, but a negative predictor for *E. coli* in well water. To account for some of these differences, one has to consider how water is sourced and stored on farm. In the case of chickens, they are more likely to defecate around and into storage containers for rain water which are often poorly covered on the farms we visited. We noticed that farms with wells and chickens, on the other hand, tended to be do a better job of maintaining protection of those wells to prevent access by chickens. Furthermore, wells mouths were much closer to the ground whereas rain storage tanks were higher up, leaving the reported impression on some farmers that poultry (or other species including dogs) could access the wells but not the rain tanks.

The results of the probit regressions confirmed our study hypothesis that the microbial quality of on-farm water is associated with farmers' demographics, socioeconomic status, and their perceptions of risk factors for WRZD transmission. Farmers with different demographic and socioeconomic status have different access to improved sources of water (*e.g.*, accessing piped water requires greater economic investment and is more likely if one lives closer to an urban centre in more expensive housing, whereas accessing river water is relatively inexpensive). Farmers also indicated, due to primarily economic considerations but also education, varying levels of access to resources for protection of water sources, storage, treatment, and distribution. Land requirements are also a consideration and if ownership or at least status of residency is tenuous, as in the case of family members residing temporarily on the land or at the house of a relative, investment of labour and capital in improving water collection, storage, and treatment is less likely. Furthermore and of considerable importance with respect to influencing mitigation strategies, if a farmer does not perceive that the risk factors for WRZD transmission are a threat to his or her livelihood or the health of his family and livestock, the farmer may not see a need to take action to improve the quality of on farm water or water storage facilities. Our probit regression results imply the importance of considering farmers' demographics, socioeconomic status, and perceptions to improve the microbial quality of water on farms. However, we were not able to show strong association with mitigating behaviour across several types of water sources. That analysis is ongoing.

Our study used a cross-sectional design examining quality of on-farm water at one point in time. However, water quality is highly likely to vary over time. For example, in developing countries, fecal contamination of water appears to be more likely during the rainy season (Costyla *et al.*, 2015). In addition to the associated factors of on-farm water quality discussed above, future studies may be needed to assess contributions of seasonality to water quality on SSI farms.

In Vietnam, rural water supply and sanitation is regulated by a number of policies in the context of the National Rural Clean Water Supply and Sanitation Strategy up to 2020 (hereafter "the strategy") (MoC, 2000). However, there has been limited progress in the implementation of the strategy and many challenges still exist with considerable room for improvement, particularly relating to engagement of stakeholders and empowerment of the rural community to ensure cleanliness of water supply and adequate on-farm water sanitation. For example, the level of stakeholder consultation for the strategy phase was not comprehensive and the participation of grassroots stakeholders (*e.g.*, farmers and local veterinarians) was limited (Le, Hall, and Cork, 2014). At the same time, studies have shown that SSI farmers and their animals are at high risk of WRZD and that water-related policies have direct important impact on human and animal health, as well as sustainability of agriculture. Therefore, revision of the strategy is in order with consideration of stakeholder involvement and empowerment.

A key discussion yet to take place with stakeholder involvement is how to promote clean rural water distribution as well as decision making for cleanliness driven by commune leaders. Our study involved local stakeholders and leaders not only in water collection but also water testing (well plate presence/ absence tests), confirmed by national laboratories. This pattern of joint responsibility and ownership of water quality problems by both local and national authorities generates improved policy dialogue and illustrates more acceptable and sustainable solutions supported by policy formulation. Thus we expect that findings from this study may be useful to assist the revision of the strategy.

Finally, trans-disciplinary approaches are recommended in revising the strategy to define clearer roles and responsibilities and to be more inclusive of stakeholders. It has been recommended that the Vietnamese government consider incorporating an EcoHealth approach to revising, formulating, and implementing government policies addressing SSI farming and water public health (Hall and Le, 2009; Hall and Dinh, 2009).

CONCLUSIONS

We hypothesized that there are differences between sources and frequency of use of drinking and domestic water among SSI farmers in the provinces of Thai Binh and An Giang. This study confirmed that SSI farms in these provinces are faced with water of low quality and variable source. Furthermore, SSI farmers' socioeconomic status and their perceptions of risk factors for WRZD transmission are associated with and may well influence the basic microbial content of water used for drinking and domestic purposes. The study also revealed that water for drinking and domestic purposes was frequently contaminated with *E. coli* and did not meet international of Vietnamese government quality standards. Although *E. coli* levels in water is recommended for establishing if a water source is recently contaminated with faeces, such faecal contamination of water is often intermittent and may not be revealed in one assessment of a single sample. Therefore, it is important to improve understanding and ability to act by SSI farmers with respect to water quality, particularly with respect to water collection and testing using simple and affordable presence/absence tests and through improvement of on-farm water public health and integrated livestock management.

Our research of on-farm water quality in Vietnam with the use of modeling of factors associated with quality of on-farm water continues. Our preliminary results addressing SSI farm water quality and SSI farmers' strategies for mitigating WRZD transmission highlight the need for improving rural water supply and sanitation, as well as water and health management training. Finally, we advocate revising the water regulatory framework/policies on SSI farms in Vietnam, particularly with respect to greater stakeholder engagement.

ACKNOWLEDGEMENTS

We thank our colleagues at the Centre for Public Health and Ecosystem Research (Hanoi School of Public Health), the National Institute of Veterinary Research, Hanoi Water Resources University, and the Vietnam Research Institute of Aquaculture No. 1 for their help during data collection of this study. The authors appreciate the funding support for this research from Grand Challenges Canada - Stars in Global Health Round 4 (Grant ID S4 0231-01) and the International

Development Research Centre (IDRC) - Doctoral Research Award Program. The funding sources were not involved in the study design, in the collection, analysis, and interpretation of data, in the writing of the manuscript, and in the decision to submit the manuscript for publication. This research was approved by the Conjoint Faculties Research Ethics Board, University of Calgary, and the Ethics Board at Hanoi School of Public Health.

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Table 1. Frequency of use of on-farm drinking and domestic water by source in Thai Binh and An Giang Provinces, Vietnam.

Province/Sources of water	Mean frequency of use for drinking by source of water ([a])					
	Drinking use			Domestic use		
	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
Thai Binh						
Rain	196	3.4***	1.3	256	2.5***	0.9
Drilled well	231	3.2***	1.3	251	3.5***	1.1
Bottled	169	2.4	1.1	108	1.2***	0.5
Pipe	61	2.4	1.4	52	1.8***	0.9
Dug Well	40	1.6***	1.0	38	1.9***	1.1
Pond	143	1.0***	0.2	209	2.9***	1.4
River/Canal	143	1.0***	0.2	251	3.2***	1.2
An Giang						
River/Canal	297	3.0	1.3	288	3.8	1.0
Pipe	243	2.6	1.7	245	1.3	0.9
Bottled	280	2.5	1.2	254	1.5	0.8
Rain	277	2.4	1.0	267	2.1	1.0
Pond	271	1.3	0.6	260	1.4	0.7
Drilled well	219	1.0	0.2	227	1.1	0.6
Dug Well	217	1.0	0.1	226	1.0	0.1

([a]) 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, to 5 = Very often

*** indicating values that are significantly different between two provinces at $p<0.01$

Table 2. Mean pH, turbidity, and *E. coli* cfu of on-farm drinking water in Thai Binh and An Giang Provinces, Vietnam.

Variable/Province	Rain water	Pipe water	Well water [e]	Bottled water	River water (fl.)
pH[a]					
Thai Binh	6.4**	6.4**	6.5**	-	-
An Giang	7.9	7.5	6.8	9.4	7.0
Turbidity (measured in Nephelometric Turbidity Unit) [b]					
Thai Binh	0.8**	0.9*	3.6	-	-
An Giang	1.3	2.0	3.9	0.8	7.6
E. coli (measured in number of E. coli colony-forming unit per 100 mL of sample water)[c]					
Thai Binh	61.8**	19.5**	27.0**	-	-
An Giang	11.1	7.1	107.1	8.0	12.8
Frequency of use[d]					
Thai Binh	3.4	2.4	2.4	2.4	1.0
An Giang	2.4	2.7	1.0	2.5	3.0

[a] = means pH of all sources of water were not smaller than "6.5" nor significantly greater than "8.5" at $p < 0.1$

[b] = means of turbidity of well and river water were significantly greater than "2" at $p < 0.01$

[c] = means of *E. coli* in all sources of water were significantly greater than "0" at $p<0.01$

[d] = Frequency of use of the source water for drinking using (1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, and 5 = Very often).

[e] =both drilled well and dug well

** indicating values that are significantly different between the two provinces at $p<0.05$; * indicating values that are significantly different between the two provinces at $p<0.1$

Table 3. Mean pH, turbidity, and *E. coli* cfu of on-farm domestic water in Thai Binh and An Giang Provinces, Vietnam.

Variable/Province	Well water [e]	Pond water	River water
pH [a]			
Thai Binh	7.1*	6.7**	7.1
An Giang	6.1	7.0	7.3
Turbidity (measured in Nephelometric Turbidity Unit) [b]			
Thai Binh	10.2	34.4***	25.3*
An Giang	31.5	59.2	62.1
E. coli (measured in number of E. coli colony-forming unit per 100 mL of sample water) [c]			
Thai Binh	356.5	2,494.7	2,757.5***
An Giang	371.4	2,950.1	780.7
Frequency of use[d]			
Thai Binh	2.2	2.9	3.2
An Giang	1.1	1.4	3.8

[a] = means pH of all water were not significantly smaller than "6.0" nor greater than "8.5" at $p < 0.1$

[b] = means of turbidity of well and river water were significantly greater than "5" at $p < 0.01$

[c] = means of *E. coli* in all sources of water were significantly greater than "20" at $p < 0.01$

[d] = Frequency of use of the source water for domestic purposes (1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, to 5 = Very often).

[e] = both drilled well and dug well

*** indicating values that are significantly different between the two provinces at $p < 0.01$; ** indicating values that are significantly different between the two provinces at $p < 0.05$; * indicating values that are significantly different between the two provinces at $p<0.1$

Table 4. Prevalence of *E. coli* in on-farm drinking water tests[a] by source in Thai Binh and An Giang, Vietnam.

Water sources	Presence of *E. coli* in on-farm water for drinking					
	An Giang			Thai Binh		
	Positive	*Total*	*Prevalence*	*Positive*	*Total*	*Prevalence*
River with flocculation	124	131	94.7	-	-	-
Rain	24	27	88.9	67	92	72.8
Pipe	61	82	74.4	19	36	57.8
Well	3	5	60.0	137	165	83.0
Bottle	19	33	57.6	1	6	16.7
Pipe (stored in reservoir)	11	20	55.0	-	-	-
Total	242	298	81.2	224	299	74.9

a. Coliplate™

Table 5. Demographic variables of 600 small-scale integrated farmers in Thai Bing and An Giang Provinces, Vietnam.

	Mean (SD)	
	Thai Binh	*An Giang*
Age in years	47.5 (11.9)	44.4 (10.5)
Years of schooling	8.2 (2.7)	5.6 (3.2)
Household size (persons)	4.2 (1.3)	4.7 (1.3)
No. of people < 18 y.o.	1.0 (0.9)	1.4 (1.0)
Years farming	11.7 (8.7)	7.6 (7.2)
Income ($CDN)	1437.58 (467.1)	1042.24 (513.1)

Table 6. Annual livestock (animals/farm/year) and fish production (kgs/farm/year) of 600 small-scale integrated farmers in Thai Bing and An Giang Provinces, Vietnam.

	Thai Binh		An Giang	
	Farms[1] (%)	*N (SD)*	*Farms (%)*	*N (SD)*
Chickens	272 (91)	33.5 (22.4)	201 (76)	11.9 (10.7)
Fish	240 (80)	1779.0 (2395)[2]	74 (25)	6296.0 (29,342)
Pigs	193 (65)	24.8 (18.9)	101 (34)	7.7 (9.7)
Ducks	126 (42)	57.1 (56.9)	119 (40)	14.1 (18.8)
Cattle	65 (22)	1.4 (1.0)	128 (43)	3.9 (2.1)

1. 300 farms reporting per province. 2. Fish are reported in kg/yr.

Table 7. Summary statistics for independent variables considered for use in regression models.

Variable name	Description	N	Mean	sd	Min	Max	Count (1)	% (1)
Age	Age of the farmers	597	45.9	11.3	17	85	-	-
DGender	Gender of the farmers (Male = 1; Female =0)	598	-	-	-	-	428	71.6
Schooling	Years of attending school	598	6.9	3.2	0	18	-	-
DIncome	Income under poverty (Poor =1; No poor = 0)	590	-	-	-	-	118	20.0
Children	Num. hhld. member < 18 years old (Yes =1; No = 0)	598	-	-	-	-	421	70.4
Experience	Years of farming	598	9.6	8.3	0	50	-	-
DOff-farm job	Had off-farm jobs (Yes =1; No = 0)	593	-	-	-	-	293	49.4
DFPR-Lvstk-Man	Man primarily resp. for lvstk. prodn. (Yes =1; No = 0)	589	-	-	-		244	41.4
DFPR-Lvstk-Wmn	Woman prim. resp. for lvstk. prodn. (Yes =1; No = 0)	589	-	-	-	-	91	15.5
DFPR-Fish-Wmn	Woman prim. resp. for fish prodn. (Yes =1; No = 0)	598	-	-	-		41	6.9
DFPR-Fish-Man	Man prim. resp. for fish prodn. (Yes =1; No = 0)	598	-	-	-	-	187	31.3
DFPR-Health-Man	Man prim. resp. for family health (Yes =1; No = 0)	591	-	-	-		131	22.2
Province	Thai Binh =1; An Giang = 0)	598	-	-	-	-	300	50.2
DFish prod	Having fish production (Yes =1; No = 0)	598	-	-	-		388	64.9
DRain for animals	Using rain water for livestock prodn. (Yes =1; No = 0)	598	-	-	-	-	392	65.6
DPond for animals	Using pond water for livestock prodn. (Yes =1; No = 0)	598	-	-	-		211	35.3
DPipe for animals	Using pipe water for livestock prodn. (Yes =1; No = 0)	598	-	-	-	-	67	11.2
DMulti-agri active.	Engage in > three agric. activities (Yes =1; No = 0)	503	-	-	-	-	436	86.7
DPoultry AI	Poultry infected with AI in the past (Yes =1; No = 0)	598	-	-	-	-	50	8.3
Npigs/yr	Number of pigs produced on-farm per year	491	11.3	16.9	0	70	-	-

Note: AI = Avian influenza, D = Dummy, Dom = Domestic, FP = Farmers' perceptions, FPR = Farmers' perceived responsibility, FPBarr = Farmers' perceived barriers to taking mitigating actions, FPBarr = Farmers' perceived barriers to taking mitigating actions, FPS = Farmers' perceived susceptibility (cont.)

Table 7 (cont). Summary Statistics for the Independent Variables (IVs) Considered for Use in Regression Models (cont.)

Variable name	Description	N	Mean	Sd	Min	Max	Count (1)	% (1)
	Independent variables relating to farmers' perceptions of:							
DFPWater quality	general water quality in the villages (Good=1; Not good = 0)	597	-	-	-	-	486	81.4
DFPBarr-Cost	cost as barriers of WRZD mitigating actions (Yes =1; No = 0)	598	-	-	-	-	239	40.0
DFPRisk rain water	risk of WRZD transm. untrtd. rain water (Yes =1; No = 0)	550	-	-	-	-	517	94
DFPS-AI-Drink	susceptibility to AI from UDW (Yes =1; No = 0)	496	-	-	-	-	469	94.6
DFPS-Diarrhea-Drink	susceptibility to diarrhea from UDW (Yes =1; No = 0)	559	-	-	-	-	554	99.1
DFPS-Coliform-Drink	susceptibility to coliform from UDW (Yes =1; No = 0)	213	-	-	-	-	213	100.0
DFPS-Parasite-Drink	susceptibility to parasites from UDW (Yes =1; No = 0)	404	-	-	-	-	402	99.5
DFPS-AI-Dom	susceptibility to AI from UDomW (Low =1; High = 0)	497	-	-	-	-	289	58.2
DFPS-Coliform-Dom	susceptibility to coliform from UDomW (Low =1; High = 0)	213	-	-	-	-	146	68.5
DFPS-Diarrhea-Dom	susceptibility to diarrhea from UDomW (Low =1; High = 0)	561	-	-	-	-	354	63.1
DFPS-Parasite-Dom	susceptibility to parasites from UDomW (Low =1; High = 0)	405	-	-	-	-	293	72.4
DSatisfy-Drink	satisfaction with source of drinking water (Low =1; High = 0)	596	-	-	-	-	244	40.9
DSatisfy-Dom	satisfaction with domestic water (Low =1; High = 0)	580	-	-	-	-	398	68.6
DAI heard	heard of AI or not (Yes =1; No = 0)	598	-	-	-	-	541	90.5
DFPHarm-Dom	harm of UDomW (Low =1; High = 0)	576	-	-	-	-	332	57.6
DFPHarm-Drink	harm of UDW (Yes =1; No = 0)	574	-	-	-	-	565	98.4
	Other Independent variables:							
DDump Waste	Dump lvstk. waste in domestic water source (Yes =1; No = 0)	547	-	-	-	-	175	32.0
DFE-Livestock Mgmt.	Engage in livestock management (Yes =1; No = 0)	598	-	-	-	-	329	55.0
DTest-dom	Have tested domestic water in the past (Yes =1; No = 0)	559	-	-	-	-	40	7.2

Notes: UDW = untreated drinking water, UDomW = untreated domestic water, and N = Number

Table 8. Probit regression results for association of presence of *E. coli* in drinking water with demographics, perception, and mitigation in Vietnam.

	RAINWATER				***WELLWATER***			
Variable	***Coef.***	***SD***	***z***	***P>|z|***	***Coef.***	***SD***	***z***	***P>|z|***
Years farming	0.0439*	0.0248	1.7700	0.0760	-0.0231	0.0157	-1.4700	0.1430
Educ (yrs)	0.0434	0.0733	0.5900	0.5540	0.0225	0.0531	0.4200	0.6720
Gender								
Male	0.2954	0.4584	0.6400	0.5190	-0.6649**	0.3186	-2.0900	0.0370
Female	1.0007*	0.5617	1.7800	0.0750	-0.2363	0.3447	-0.6900	0.4930
Chickens raised (d)	0.9681**	0.4370	2.2200	0.0270	-0.9968*	0.5334	-1.8700	0.0620
Fish raised (n)	0.3256	0.4740	0.6900	0.4920	0.4286	0.6318	0.6800	0.4970
Susc to AI (domstc wtr)	-0.9139*	0.4877	-1.8700	0.0610	-0.4342	0.2725	-1.5900	0.1110
Susc to AI (pond wtr)	0.7412	0.5226	1.4200	0.1560	n/a			
Barriers: not knowing	1.0759**	0.4921	2.1900	0.0290	0.0833	0.2963	0.2800	0.7790
Barriers: peer pressure	-0.7924	0.5123	-1.5500	0.1220	n/a			
Livestock management	-1.3004**	0.5423	-2.4000	0.0160	-0.8941***	0.3617	-2.4700	0.0130
Water management	1.1422**	0.5793	1.9700	0.0490	0.8071**	0.3753	2.1500	0.0320
Mitigation: lost income	-0.7204	0.4536	-1.5900	0.1120	-0.3617	0.2898	-1.2500	0.2120
Mitigation: peers	-0.5092	0.4065	-1.2500	0.2100	0.9157*	0.5194	1.7600	0.0780
Mitigation: disease	0.6563	0.4405	1.4900	0.1360	-0.2656	0.3849	-0.6900	0.4900
On-farm income	-0.4451	0.5612	-0.7900	0.4280	0.1118	0.1368	0.8200	0.4140
Satisf w/ drinking wtr	1.1051	0.9457	1.1700	0.2430	-0.2568	0.5586	-0.4600	0.6460
(constant)	-2.6090	1.4312	-1.8200	0.0680	1.9459	1.0307	1.8900	0.0590

Rainwater:
N = 121
LR chi2(17) = 40.88 Prob > chi2 = 0.0010
Log likelihood = -48.4151 Pseudo R2 = 0.2968
Correctly classified = 76.86%

Wellwater:
N = 146
LR chi2(15) = 24.27 Prob > chi2 =.0607
Log likelihood = -73.5927 Pseudo R2 = 0.1415
Correctly classified = 76.03%

Note that "gender" represents two different dummy variables for gender of decision makers. The "Male" dummy variable captures gender of decision maker related to livestock management and the "Female" dummy variable captures gender of decision maker related to on-farm water storage management.