Factors Affecting the Prevalence of Fecal Pathogen Infections: Approaches for Health Risk Protection

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ABSTRACT

Septic tank sludge or fecal sludge (FS) is often discharged on public areas without any treatment, causing environmental and adverse public health effects. Millennium Development Goal 7c (MDG 7c) targets improved access to water and sanitation because 85% of the world's total FS is often discharged on public areas. Like other countries, Thailand faces fecal slugde management (FSM) problems leading to significant fecal pathogen infections, especially in the north and northeastern regions. This study assessed the effects of unsafely-managed FS on human health risks in two cities, Natan City and Tham Lod City in Thailand, that have relatively high liver fluke and diarrhea infections, and identified the factors relating to FSM practices that affect the prevalence of liver fluke and diarrhea infections due to FS. Specific measures were proposed in delivering integrated FSM solutions and health risk protection toward the Sustainable Development Goal No. 6 (SDG6) targets of safely managed sanitation and hygiene services. Based on data collected from these cities from February to May 2019, factors relating to FSM practices that affect the prevalence of liver fluke and diarrhea infections were identified and analysed using multiple regression analysis. Based on the findings, specific measures in delivering integrated FSM solutions and health risk protection toward the Sustainable Development Goals 6 (SDG 6) are proposed. Because no FS treatment facilities operate in Natan City and Tham Lod City, almost 100% of FS is discharged directly into open drains, resulting in diarrhea and liver fluke infections among local people. The findings identified the factors relating to FSM practices that affect the prevalence of liver fluke and diarrhea infections and proposed specific measures in delivering integrated FSM solutions and health risk protection, such as promoting education programmes, avoiding direct FS discharges into open drains and nearby streams, and providing innovative FSM technologies to eradicate fecal pathogen infections.

1. INTRODUCTION

Most cities in low and middle income countries face adverse public health effects due to inadequate fecal sludge management (FSM) practices. Despite the target of the Millennium Development Goals 7c (MDG 7c), which aims to improve access to water and sanitation by 2015, 85% of the world's total FS is directly discharged onto public areas without any treatment, causing environmental pollution and public health problems (Al-Mohammed et al., 2010; Yoshida et al., 2019). Unsafely-managed FS contains pathogens leading to significant fecal pathogen infections worldwide, especially among Southeast Asian nations such as Thailand, Myanmar and Cambodia. Previous studies by Taweesan et al. (2015) and Bisung et al. (2015) emphasized the inadequate FS collection and FS treatment facilities leading to the contamination of water resources and groundwater. A similar finding was confirmed by the World Health Organization and the United Nations International Children's Emergency Fund (2017) which stated that the prevalence of fecal pathogen infections by food- and water-borne transmitted helminths in Southeast Asian Nations has been found in areas of these

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countries characterized by poor sanitation and hygiene. Among food- and water-borne transmitted helminth infections, 127 million people in Asian Countries are infected with *Ascaris lumbricoides* of which 115 million are infected with *Trichuris trichiura* and more than 70 million have hookworm infections (Torgerson and Macpherson, 2011).

In Thailand, for example, statistics released in 2017 by the the Department of Disease Control revealed that almost 30,000 people die from liver fluke infections yearly, an average of 76 deaths daily. Although the Royal Thai Government has implemented various national health campaigns and improved public access to medical services which aim to reduce liver flukes, the decrease in the infection rate of helminth-led liver disease remains a huge challenge countrywide. One of the most common causes of helminth-led liver disease is a lack of safely-managed sanitation, particularly inadequate FS treatment and improper FSM, despite the fact that about 99% of the Thai population have been able to access improved drinking water and sanitation facilities in the last decade (World Health Organization and United Nations International Children's Emergency Fund, 2017).

Several studies have attempted to determine the factors which influence the prevalence of fecal pathogen infections, but the effects of unsafely-managed FS on human health risks such as liver fluke and diarrhea infections are commonly ignored (Bdir et al., 2010; Sripa et al., 2010; Dufour et al., 2012; Sithithaworn et al., 2012; Prasongwatana et al., 2013; Aggarwal et al., 2017; Freeman et al., 2017; Penakalapati et al., 2017; Wolf et al., 2019). Understanding the factors relating to FSM practices that affect fecal pathogen infections due to unsafely-managed FS is needed to improve the efficiency of the entire management system. These factors are further exacerbated by financial constraints and the limited awareness of the central government in spite of their declaration to comply with the Sustainable Development Goals (SDG) by 2030, including SDG 6, “Clean Water and Sanitation”. For example, urban and peri-urban areas of Cambodia employ on-site sanitation systems, i.e., cesspools or septic tanks, to treat toilet wastewater, but the FSM practices are poorly managed, causing fecal pathogen infections, e.g., diarrhea (Ferrer et al., 2012; United Nations World Water Assessment Programme, 2015).

Furthermore, due to inadequate FS collection and treatment, and lack of FS treatment facilities, most FS collected by unlicensed FS collection operators, is directly discharged in unsanitary ways leading to contaminated water resources and groundwater (Frenoux and Tsitsikalis, 2014). These findings were confirmed by Brown et al. (2013), who stated that one of the most common causes of diarrhea infections is a lack of safe sanitation and clean water. The aims of this study were: (i) to assess the effects of unsafely-managed FS on human health risks of two cities in Thailand that have relatively high liver fluke and diarrhea infections; (ii) to identify the factors relating to FSM practices that affect the prevalence of liver fluke and diarrhea infections due to unsafely-managed FS; and (iii) to propose specific measures in delivering integrated FSM solutions and health risk protection toward Sustainable Development Goal no. 6 (SDG6) targets for safely managed sanitation and hygiene services.

2. METHODOLOGY

2.1 Study areas

This study was conducted from February to May 2019 in two cities: Natan City in Sakon Nakhon Province, Northeastern Thailand, and Tham Lod City in Mae Hong Son Province, Northern Thailand, as shown in Figure 1. These cities had a high prevalence of liver fluke and diarrhea infections (>20%) during the period of 2013 to 2017, respectively (Department of Disease Control, 2017). These two study areas were selected using the Getis-Ord Gi* technique by considering the high prevalence rates of liver fluke and diarrhea infections. The Getis-Ord Gi* technique is a statistical technique used to identify hot spot areas by considering incident data, i.e., the number of liver fluke and diarrhea infections, while including selected impact attributes in the analysis. FSM data were collected from 300 households per city by field visits, questionnaire surveys and face-to-face interviews with key informants (such as vacuum truck staff, FS plant operators, local leaders, farmers and concerned households). The key informants who contributed to this study varied considerably: vacuum truck staff (3%); FS plant operators (3%); local leaders (10%); village health volunteer (8%); households (58%); and others (18%).

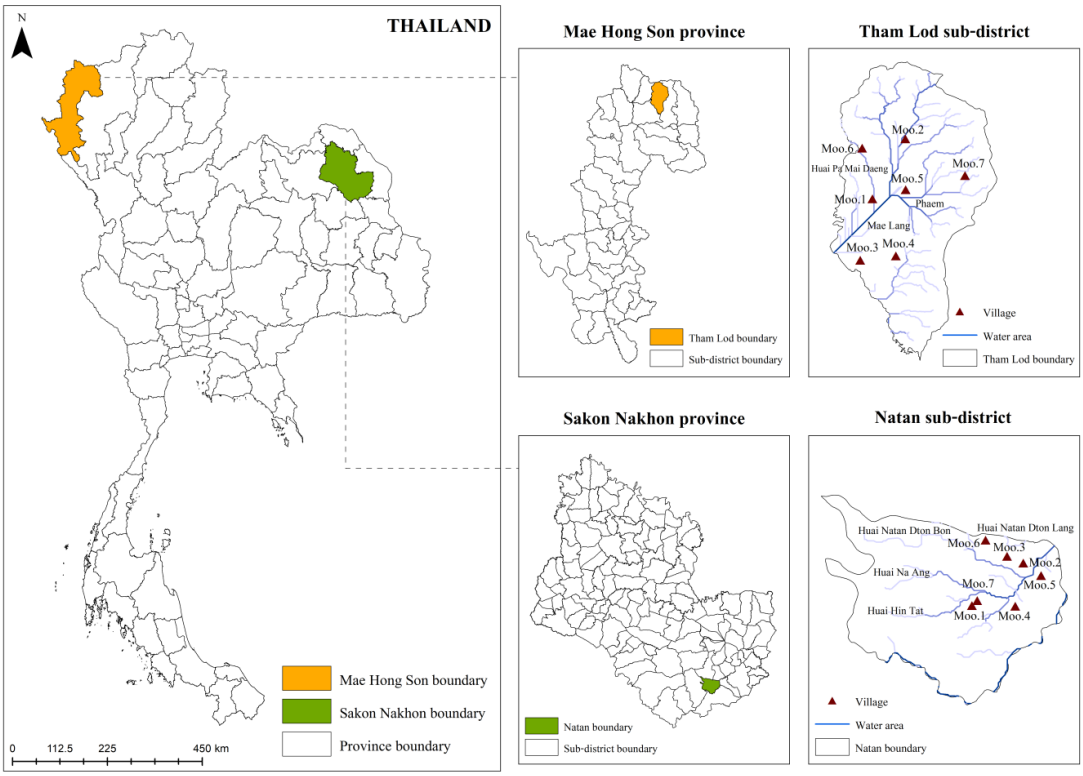

Figure 1. Study areas

2.2 Factor identification for data collection

At present, several factors affect the prevalence of liver fluke and diarrhea infections. Reviews of the relevant literature from various countries were conducted (Pham-Duc et al., 2011; Ferrer et al., 2012; Huong et al., 2014; Molla et al., 2014; Jeff et al., 2017). It was found that the significant factors included: (1) socio-demographic variables (sex, age, education level, income and occupation) of those who regularly have contact with FS (vacuum truck staff, FS plant operators and farmers); (2) personal hygiene (drinking water from natural resources, water supply from natural resources, consumption of treated water, raw or undercooked fish and washing hands before meals); (3) FSM practices (type of on-site sanitation systems, direct FS discharges into open drains, frequency of FS emptying and open defecation); and (4) knowledge of liver fluke and diarrhea infections and their relationships with FSM. The percentage of liver fluke and diarrhea infections were obtained from the official records of each village in these cities during the period of 2013 to 2017 (Department of Disease Control, 2017). In addition, the presence of liver fluke eggs in septic tanks, vacuum trucks, and FS treatment plants in Natan City was assessed in order to correlate the data on FSM practices in response to liver fluke infections.

2.3 Data analysis

Descriptive statistics, particularly percentage distribution, was applied for preliminary analyses and to present the effects of unsafely-managed FS on the prevalence of liver fluke infections in this study. For the cities considered to have unsafely-managed FS, the FS collected from households was directly discharged into open drains or nearby water resources. Cities were considered to have a “high” prevalence of infection rates when the prevalence of liver fluke and diarrhea infections was more than 20%, “moderate” when the prevalence infection rates were from 10 to 20% and “low” when the prevalence infection rates were less than 10% (Huong et al., 2014). Factors relating to FSM practices that affect the prevalence of liver fluke and diarrhea infections were identified using multiple regression analysis. Regression models were developed to describe the relationship between fecal pathogen infections and other important factors. Cronbach’s alpha was adopted to measure how the combined factors related to the extent of fecal pathogen infections in the range 0.80 to 0.85 which indicated a good correlation.

3. RESULTS AND DISCUSSION

3.1 Effects of unsafely-managed FS on human health risks

The effects of unsafely-managed FS on the prevalence of liver fluke infections are shown in Figure 2. It can be seen that all villages in Natan City were found to have a "high" prevalence of liver fluke infections (more than 20%). The results presented in Figure 2 indicate that unsafely-managed FS had significant direct effects on the prevalence of liver fluke infections (r=0.72). One of the most common causes of liver fluke infection was a lack of safely-managed FS, particularly inadequate FS treatment and improper FSM. A similar study was documented by the Department of Disease Control (2017), showing that although 99% of the Thai population have access to improved sanitation facilities, i.e., latrines, the decrease in the rate of liver fluke infections remains a huge challenge countrywide. Previous studies by Aggarwal et al. (2017) and Chudthaisong et al. (2015) reported that food-borne parasitic infections were correlated with a lack of FSM facilities and personal hygiene factors. Similar studies were documented by Lindahl et al. (2015), Grundy-Warr et al. (2012), and Yoshida et al. (2019) showing that the significance of direct contact with FS was found to be an influential factor on the prevalence of liver fluke infections.

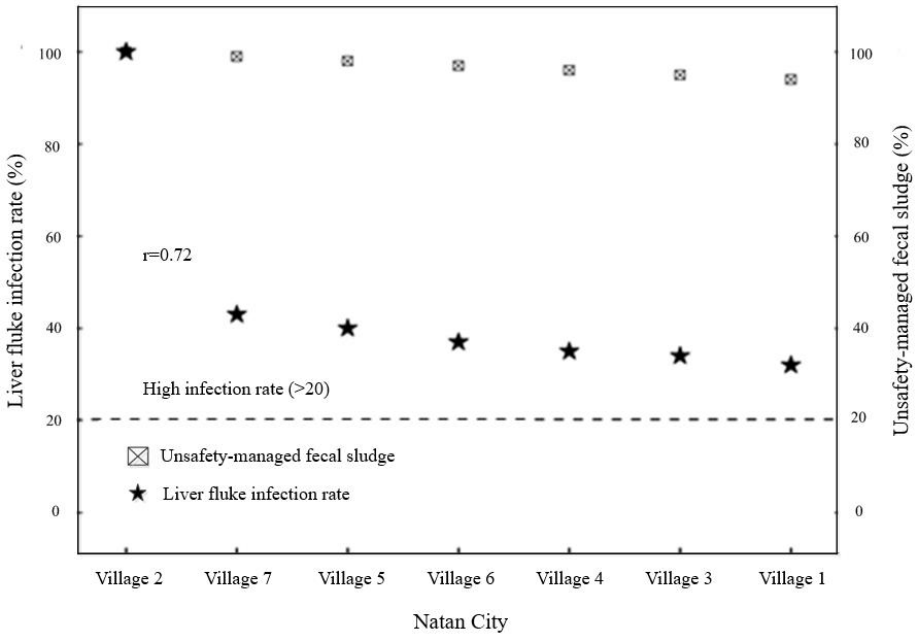

Figure 2. Effects of unsafely-managed FS on the prevalence of liver fluke infections in Natan City, Sakon Nakhon Province, Thailand

The effects of unsafely-managed FS on the prevalence of diarrhea infections are presented in Figure 3. It can be seen that 5 of the 7 villages surveyed were found to have a "high" prevalence of diarrhea infections; only two of the villages surveyed reported less than 20%. The results of Figure 3 show the significance of unsafely-managed FS directly affects the prevalence of diarrhea infections (r=0.80). From the survey results, it was found that the major reason for FSM complaints was improper FS handling and disposal practices. Most community members in Tham Lod City could be at risk from adverse health impacts through consuming contaminated fish, fruit or vegetables. Related studies by Bisung et al. (2015) emphasized that one of the most common factors of diarrhea infections is inadequate FSM services affecting unsafe drinking water. Improper FSM often leads to contamination of water resources and groundwater, and subsequent diarrhea infections among the people concerned, especially in the absence of water resources. To address these problems, personal hygiene programs should be introduced to raise public awareness of unsafely-managed FS and to better understand the importance of safe water and FSM practices. Similar findings were obtained by Jung et al. (2017), showing the effects of neighbourhood and household sanitation conditions on diarrhea morbidity.

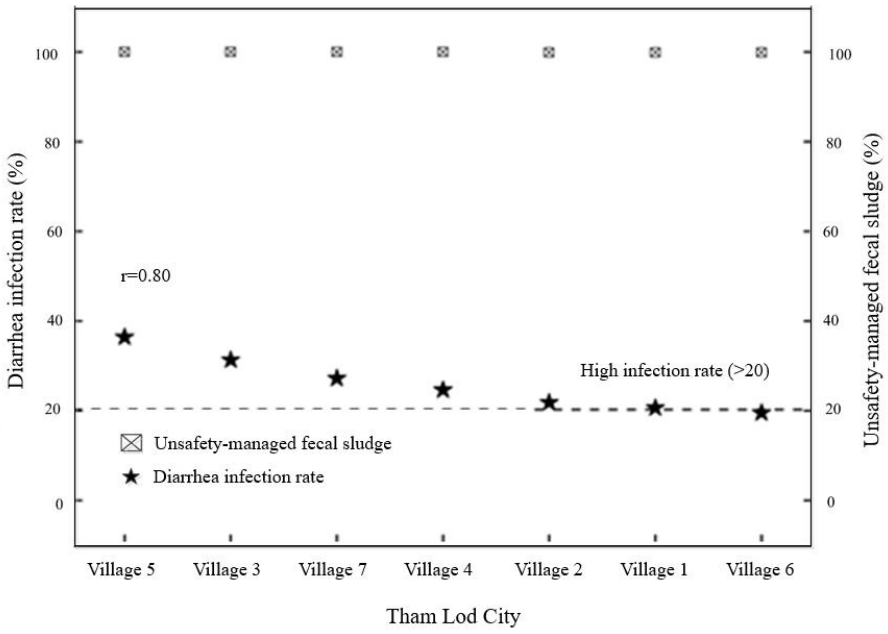

Figure 3. Effects of unsafely-managed FS on the prevalence of diarrhea infections in Tham Lod City, Mae Hong Son Province, Thailand

3.2 Factors affecting the prevalence of liver fluke and diarrhea infections due to unsafely-managed FS

The relationship between FSM practices and liver fluke infections are shown in Figure 4. Model HLF shows a strong relationship (adjusted R^2=0.80) between a set of selected factors and rates of liver fluke infection indicators (Equation (1)) in Natan City, Sakon Nakhon Province. Four significant factors included drinking water from natural resources, direct FS discharges into open drains, consuming raw or undercooked fish and knowledge of liver fluke infections indicated strong and fair significant effects on the prevalence of liver fluke infections (Figure 4). From the survey results, most households surveyed in Natan City lacked adequate sanitation and FSM facilities, especially farmers using temporary huts with no latrines leading to the possibility of FS pollution of water resources, including liver fluke eggs. The presence of liver fluke eggs were found in 60% of the FS samples collected in septic tanks. This result implies that inadequate FSM facilities are directly associated with liver fluke infections. From the survey results, more than 50% of the households interviewed in Natan City stated that defecation behaviors were common practice for farmers, as well as consumption of raw or undercooked fish. A related study by Sithithaworn et al. (2012) documented that people in Natan City normally consume raw or semi-cooked food regularly. A study by Ziegler et al. (2011) showed that the prevalence of liver fluke infections depended not only on inadequate FSM practices, but also personal hygiene and knowledge of liver fluke infections. At present, although the Thai government is implementing health campaigns on liver flukes in Thailand, the lack of sustained funding and continuous campaigns are the main reasons for the poor awareness of the local people toward fecal pathogen infections.

$$H_{LF} = 30.457 - 1.993(\text{DRINKING}^{***}) + 2.282(\text{DIRECT FS}^{***}) + 0.546(\text{FISH}^{***}) + 0.716(\text{LV KNOWLEDGE}^{***}) + 0.027(\text{OCCUPA}^{*}) \quad (1)$$

Model HDA provides a set of significant factors correlating to the prevalence of diarrhea infections (adjusted R^2=0.85) (Equation (2)), namely, income and drinking water from natural resources in Tham Lod City, Mae Hong Son Province (Figure 4). This finding implies that people with low incomes can not afford the FS treatment facilities. A similar finding was confirmed by Bisung et al. (2015) which showed that low income and unemployment were barriers to achieving “safe water and sanitation”. Most of the surveyed households in Tham Lod City consume drinking water and use a water supply from natural resources without any treatment, causing more diarrhea infections as documented by Jung et al. (2017) and Ferrer et al. (2012). In this respect, data on risk assessment concerning fecal pathogen infections should be provided for FSM. In addition, available innovative FSM technologies such as solar septic

tanks are strongly recommended to reduce fecal pathogen infections before discharge into water resources as documented by Koottatep et al. (2014).

$$H_{DA} = 1892.542 - 1.651(INCOME^{**}) + 0.688(DRINKING^{**}) + 1.344(OCCUPA^{*}) + 2.182(AGE^{*}) + 1.688(TREATED^{*}) \quad (2)$$

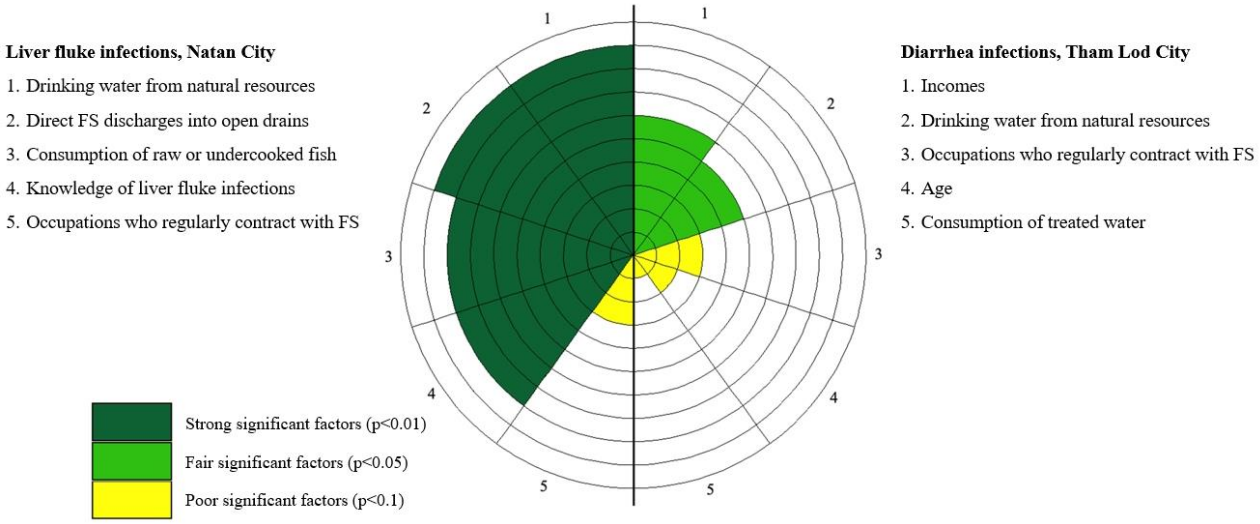

Figure 4. Factors affecting the prevalence of liver fluke and diarrhea infections

4. CONCLUSION

In this study, the effects of unsafely-managed FS on human health risks, as well as the factors relating to FSM practices that affect the prevalence of liver fluke and diarrhea infections were identified and analysed using multiple regression analysis. Results of the assessment and their significant factors analysed in this study could be used to propose specific measures in delivering integrated FSM solutions and health risk protection to comply with the Sustainable Development Goal (SDG) in 2030 including SDG 6 "Clean Water and Sanitation". Although about 99% of the Thai population have access to safe latrines, most of the surveyed households were found to have unsafely-managed FS leading to liver fluke and diarrhea infections. In this respect, FS problems need to be properly managed to eradicate liver fluke and diarrhea infections. The findings identified the significance of unsafely-managed FS which had direct effects on the prevalence of liver fluke and diarrhea infections in these cities. Four significant factors strongly affected the prevalence of liver fluke infections in Natan City, Sakon Nakhon Province which included: drinking water from natural resources, direct FS discharges into open drains, consuming raw or undercooked fish and lack of knowledge of liver fluke infections. Specific measures to reduce liver fluke infections were proposed such as promoting education programmes relating to FSM practices and fecal pathogen infections and avoiding direct FS discharges into open drains and nearby streams.

With regard to Tham Lod City, Mae Hong Son Province, there are several significant factors that correlated with the prevalence of diarrhea infections which included income and drinking water from natural resources. In this respect, innovative FSM technologies such as solar septic tanks and promoting health education campaigns are strongly recommended to reduce fecal pathogen infections.

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