International Annals of Science
ISSN: 2456-7132
Volume 6, Issue 1, pp. 18-27, 2019
DOI: https://doi.org/10.21467/ias.6.1.18-27

SHORT REVIEW

Cryptosporidium in the Philippines

Ryan V. Labana

College of Science, Department of Biology, Polytechnic University of the Philippines, Sta. Mesa, Manila, Philippines

* Corresponding author email: rvlabana@pup.edu.ph

Received: 07 August 2018 / Revised: 02 October 2018 / Accepted: 12 October 2018 / Published: 14 October 2018

ABSTRACT

This short review provides an overview regarding the research findings on the occurrence of *Cryptosporidium* in the Philippines. It seeks to set conjecture about its possible role on the increasing waterborne disease incidences in the country. Intensive search of journal articles was done among major databases, online. The first report of *Cryptosporidium* infection in the country was in 1985. Past more than 30 years, *Cryptosporidium* is not yet well-understood in the Philippines, but an increasing research interest has been observed among Filipinos in the past few years. Recently, waterborne transmission of the infection appeared in the studies to be more potent than zoonotic and person-to-person transmissions. An improvement on the detection methods was also observed, giving an improved knowledge on the molecular diversity of *Cryptosporidium* in the country. Despite these improvements, the paucity of the data regarding the impact of *Cryptosporidium* to the public health in the Philippines is still apparent. One Health approach is recommended to fully understand the interconnections between human, animal, and environment as reservoirs of the infective stage of the parasite. Dedication of the researchers in understanding their geographical distribution, molecular diversity, and environmental and climatic behaviour will eventually uncover the public health implications of *Cryptosporidium* in the country.

Keywords: *Cryptosporidium*, Philippines, Protozoan, Public health, Waterborne, Zoonotic

1 Introduction

Cryptosporidium is a waterborne parasite that has currently surfaced as the major etiologic agent of waterborne diseases across the globe making it an important threat to the global public health [1]. The overall burden of *Cryptosporidium,* as well as its diagnostics and epidemiology, are well-studied in many countries [2]. Recently, an increasing interest in studying *Cryptosporidium* was also observed in the Philippines. In the past two years, this protozoan has been detected from various animal groups in the country including green mussels, edible bivalves, dogs, and chicken [3-5]. Interestingly, the parasite-infected green mussels and edible bivalves are available in public markets for human consumptions. On the other hand, dogs and chicken are free-roamers in most rural communities. This close contact between infected animals and humans increases the risk of widespread *Cryptosporidium* infections in the country [6]. The water system in the country was also reported to be contaminated with *Cryptosporidium*. In a study conducted in public recreational pools in Laguna, all the examined swimming pools were detected with *Cryptosporidium* [7]. A high occurrence rate was also observed in Metropolitan Waterworks and Sewage System (MWSS), a major source of water for household's use in Metro Manila and its neighbouring provinces [8]. A contamination was also detected in a creek and a river from an indigenous community [5]. These reports are timely essential especially that Philippines is currently fronting issues on the accessibility of clean water due to continuous industrialization and urbanization in the country [9]. Waterborne diseases are now causing 55 deaths per day as reported from the different regions in the Philippines [10]. Despite of the reported incidence of *Cryptosporidium* in various animal groups and water sources, this parasite is not mentioned in cases of waterborne diseases in the country.

This paper presents a brief review of the accessible documented studies on the occurrence of *Cryptosporidium* in the Philippines. All studies related to *Cryptosporidium* in the Philippines were obtained through intensive search of journal articles from the databases of World Health Organization, PubMed, Mendeley, Google Scholar, Research Gate, and all Philippine journal publications accredited by the Commission on Higher Education. It seeks to understand the development of *Cryptosporidium* research in the country to determine gaps in understanding the role of this parasite to the malady on waterborne diseases in the country.

1.1 The Parasite

Cryptosporidium, a genus under the subphylum Apicomplexa, is a waterborne parasite. Currently, it has 22 known species with *C. hominis* affecting only human. *C. parvum*, which was first believed to be the sole species isolated from humans, also infects a range of animal-hosts. Several other genotypes were recognized throughout the advent of molecular studies that sought to understand the epidemiology and transmission of this parasite. The genotypes *C. bovis* (cow), *C. canis* (dog), *C. meleagridis* (bird), *C. felis* (cat), *C. muris* (rodents), and *C. cuniculus* (rabbit), are not only associated to their respective hosts but also to humans. This wide range of hosts enables *Cryptosporidium* to become ubiquitous in nature [11]. *Cryptosporidium* is a microscopic parasite measuring 4-6μm. Upon transmission, the oocyst excysts in the gut and releases the sporozoites. It then inhabits the microvillus border of the epithelium mucosal of its host. In the epithelial cells, it undergoes two generations of merogeny followed by sexual developmental stage producing micro- and macrogametes. The fusion of these gametes forms zygote that develops into oocyst with four naked sporozoites. The oocyst can be thin-walled, which causes autoinfection, or thick-walled, which persists in the environment for periods of time. This life cycle is completed within a single host [12].

The thick-walled oocysts of *Cryptosporidium* can resist various conditions in the environment. They can survive in water and soil for months due to a suitable moisture and temperature that supports their fecundity [13]. Their microscopic size enables them to pass through traditional filtration system contaminating drinking and recreational water system, soil, food, animals [14], and vectors like houseflies and cockroaches [15]. While waterborne transmission is the most common source of infection [6], person-to-person, zoonotic, and food borne transmissions have also been widely reported in many cases of disease outbreaks, worldwide [11-12].

As low as ten oocysts can already cause infection. The severity of the disease depends on the immune status of the host. It is self-limiting in immunocompetent patients, but the symptoms could last for months among the immunocompromised. The clinical presentations of *Cryptosporidium* infections include intermittent watery diarrhoea with mucus flecks, fever, abdominal cramps, nausea, anorexia, disseminated infections involving the gallbladder and respiratory tract, stunted growth among children, cognitive impairment, and other presentations especially in patients with immunodeficiency virus [16-17].

1.2 Global Perspective on *Cryptosporidium* Infections

Cryptosporidium infection was known to be endemic in the developing countries, but this is changing based on the most recent reviews of the documented outbreaks of waterborne diseases across the globe [1]. *Cryptosporidium,* together with *Giardia lamblia*, was the common etiologic agent of waterborne disease outbreaks with the most recorded incidence in the developed countries of North America, Europe, Australia and New Zealand [1,18-19]. Limited data of outbreaks in the developing countries like Philippines was suspected as a false representation of the real situation due to the lack of documentation schemes [18-19]. In California, USA, for example, an established surveillance for *Cryptosporidium* is being regularly done for an estimated six million people via California Emerging Infections Program [20]. Meanwhile, detection of *Cryptosporidium* in the Philippines is not a part of the routinely fecalysis. In fact, among the ten countries of the Association of Southeast Asian Nations (ASEAN), no record of *Cryptosporidium* in water systems was found in Brunei Darussalam, Cambodia and Indonesia. This scarcity of data blurs the real scenario of waterborne parasite transmission in these regions. This shortcoming is occurring in many parts of Asia, Africa, and Latin America. Also, developing countries opt out from effective and sensitive detection methods of protozoa due to its high cost. Thus, epidemiological data of *Cryptosporidium* in these countries are limited making its implications to the public health, ignored [21].

2 Increasing Research Interest on *Cryptosporidium* in the Philippines

There is a paucity of studies on *Cryptosporidium* in the Philippines (N=27; in 33 years) but the scientific interest on this protozoan is currently increasing (Figure 1).

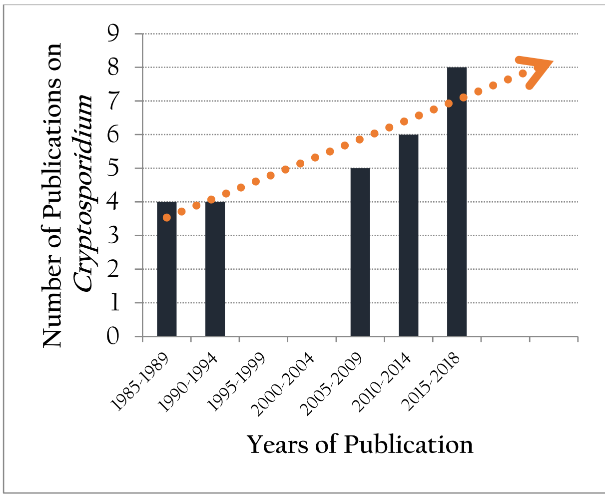

Figure 1: *Forecasted trend and the number of publications on Cryptosporidium in the Philippines.*

Nine years after the publication of the first study on *Cryptosporidium* in the country, in 1985 [22], Filipinos had momentarily stopped studying about this protozoan. Only in 2005, 10 years after the last published study in 1994, when the occurrence of *Cryptosporidium* in the Philippines had again appeared in the scientific journals. Together with the renewed interest of the Filipino researchers on *Cryptosporidium,* is the utilization of the more sensitive detection protocol. The immunofluorescence antibody (IFA) test was first used among Filipino cancer patients in 2005 [23]. In 2007, the Filipino researchers became more interested about the public health implications of *Cryptosporidium* in the country. A survey on *Cryptosporidium* infection was carried out among non-diarrheic subjects in two squatter areas in Metro Manila [24]. It was followed in 2008 by a wide-scale detection of this protozoan among 3,456 diarrheic patients widely distributed in the three major islands of the Philippines: Luzon, Visayas, and Mindanao [25]. In the same year, the first molecular detection of *Cryptosporidium* from animal hosts in the Philippines was reported [26]. The scientific interests of Filipinos in *Cryptosporidium* continued until the recent years. From the inception of *Cryptosporidium* research in the Philippines in 1985, to the release of the latest findings on *Cryptosporidium* in the indigenous community on September 2018 [5], Filipino researchers have been fairly responsive to the necessities of understanding this etiologic agent of diarrheal diseases. In the span of 33 years, several highlights on *Cryptosporidium* research in the Philippines have been reported to the scientific community (Figure 2) giving this issue a light to a way forward.

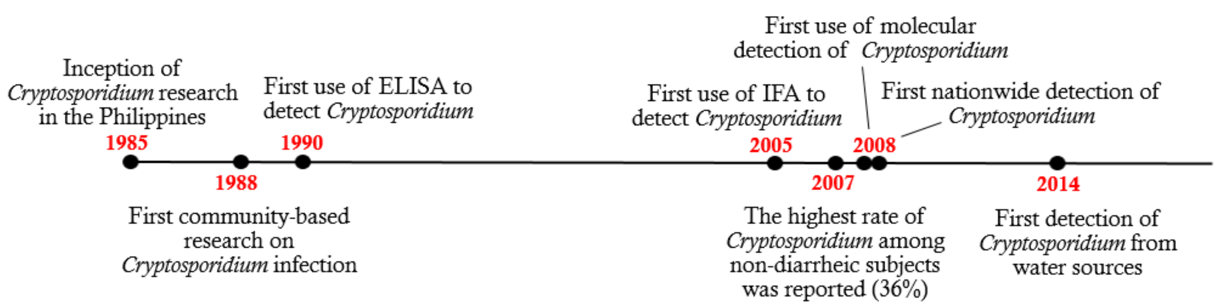

Figure 2: *Highlights of researches on Cryptosporidium in the Philippine*

3 Diagnostic Techniques Commonly used in the Philippines

The most widely used methods for the diagnosis of *Cryptosporidium* in the Philippines is through morphological identification of the oocyst after the application of a stain as Kinyoun acid-fast staining and modified Ziehl-Neelsen staining. It is the common method used in the country due to its relatively low cost and easy preparation. The quite expensive immunofluorescence antibody (IFA) tests and enzyme-linked immunosorbent assay (ELISA) was severally used starting 2005 either as a sole method or in combination with staining and molecular techniques. The IFA test is noted with 97% sensitivity for protozoa detection [27].

Molecular detection of *Cryptosporidium* was first used in the Philippines in 2008 through amplification of a fragment of the *Cryptosporidium* heat-shock protein gene by polymerase chain reaction (PCR). In the same study, the genotypes *C. parvum* and *C. canis* were first successfully identified in the country [26]. In another study, the detection of genomic DNA extract from human and caprine faecal samples was done to identify PCR positive reactors for *C. parvum* DNA [28]. In 2013, *Cryptosporidium* was detected from faecal DNA samples at the 18S rRNA locus and at the actin gene locus via two-step nested PCR. That study was also the first to report other *Cryptosporidium* genotypes detected in the Philippines through phylogenetic analysis. The genotypes identified were rat genotype I, rat genotype II, rat genotype III, rat genotype IV, *C. muris, C. scrofarum,* and "*C. suis*-like genotype" [29]. Other genotypes were identified in 2016 in a study conducted among Philippine bats. Bat genotype II were identified while bat genotypes V, VI, and VII were proposed as novel genotypes of *Cryptosporidium* [30]. Recently, the genotypes *C. parvum* and *C. hominis* were identified from Asian green mussels sold in wet markets of Quezon City in the Philippines, through DNA sequence analysis of the 18S rRNA genes [3]. *C. meleagridis*, which causes infections not only in avian species but also in humans (at a low rate), were also identified from edible bivalves in Manila Bay [4].

Microscopic examination of *Cryptosporidium* is laborious and requires professional training. The sensitivity of acid-fast staining is considered low and is insufficient in demonstrating the presence of the parasite, due to other acid-fast organisms like fungal spores that resembles with *Cryptosporidium* upon detection [27]. ELISA has been reported to be more sensitive than acid-fast staining by 10 times [31]. Meanwhile, numbers of PCR-based assays have been noted with considerably higher sensitivity and specificity. Moreover, molecular detection is able to identify species and subtype level which is important in determining virulence and pathogenicity of the protozoan [32-33]. The low sensitivity of acid-fast staining techniques, the commonly used detection techniques in the country, could have underestimated the prevalence of *Cryptosporidium* infections among most of the studies conducted in the Philippines.

4 Reported Prevalence of *Cryptosporidium* in the Philippines (1985 - Present)

4.1 Infection in Humans

Reports on the prevalence of *Cryptosporidium* infection in the Philippines varied depending on the population examined (Table 1). The prevalence of infection among children (≤10 years old) was ranging from 1.8% to 19.3%, while among the immunocompromised individual, who were cancer patients, was 28.3%. The prevalence rates observed among adults ranged from 0.6% to 21.1%. A national mapping of *Cryptosporidium* infections can be a major leap on understanding Cryptosporidiosis in the Philippines, but a costly detection process can impede its completion. The high prevalence rates of *Cryptosporidium* infections among goat raisers [28] and cancer patients [23] are interesting results. Despite the fact that both studies used a more sensitive molecular detection, they also propose future researchers to cover other susceptible groups than children, which were the common study-population in the Philippines.

Table 1: *Reported prevalence rates of Cryptosporidium infections among humans in the Philippines.*

Year Reported	Human Population (Location)	*n*	Children		Adults		Immune-compromised		Unspecified		Overall %	Ref
			+	%	+	%	+	%	+	%		
1985	Children: 6-20 months old (Manila)	735	21	2.90%	-	-	-	-	-	-	2.90%	[22]
1986	Children and adults (Manila)	339	6	1.80%	2	0.60%	-	-	-	-	2.40%	[34]
1988	Diarrheic patients (Palawan)	19	1	5.30%	0	0.00%	-	-	-	-	5.30%	[35]
1989	Patients at San Lazaro Hospital (Metro Manila)	735	-	-	-	-	-	-	19	2.60%	2.60%	[36]
1990	Children: 1-24 months old (Metro Manila)	823	70	8.50%	-	-	-	-	-	-	8.50%	[37]
1994	Children: under 12 years old	236	6	2.50%	-	-	-	-	-	-	2.50%	[38]
2005	Filipino cancer patients	53	-	-	-	-	15	28.30 %	-	-	28.30%	[23]
2007	Inhabitants of impoverished communities (Manila)	150	29	53.7%	25	46.3%	-	-	-	-	36.00%	[24]
2008	Diarrheic patients (Luzon, Visayas, Mindanao)	345 6	63	1.80%	3	0.10%	-	0%	-	0%	1.90%	[25]
2011	Active duty personnel during exercise *Balikatan* 2009	10	-	-	0	0.00%	-	-	-	-	0.00%	[39]
2012	Goat raisers (Aurora)	678	-	-	143	21.1%	-	-	-	-	21.10%	[28]
2018	Indigenous peoples (Ifugao)	137							39	28.5%	28.50%	[5]

Another striking result was the high prevalence rate of *Cryptosporidium* infection among the inhabitants of two impoverished communities in Metro Manila. This was the first attempt to conduct a surveillance of the infection among non-diarrheic subjects in the urban communities. The study had described the poor water, hygiene, and sanitation (WASH) practices of the people in the communities of Singalong and Leveriza in Metro Manila [24]. The most recent report on *Cryptosporidium* infection among humans shows an over-all prevalence rate of 28.5%. The same study reported risk factors of *Cryptosporidium* infection in the indigenous community of Boliwong, Philippines [5].

4.2 Infection in Animals

Table 2 presents the reported prevalence rates of *Cryptosporidium* infections among animal groups in the Philippines. There is a considerable higher prevalence rates of *Cryptosporidium* infection in animals compared to the examined human population. Aside from one infected cow examined in 1985 [35], Asiatic clam in Aurora had the highest prevalence rate [40] followed by edible bivalves in Manila Bay [4], green mussels in various wet markets around Metro Manila [3], and Asian clams in Laguna de Bay [41]. In decreasing order, *Cryptosporidium* was also detected in dogs, chicken, rats, goats, pig, water buffaloes, and bats.

Clams, mussels, and other edible bivalves are cheap ingredients of common delicacies in the Philippines. It is being cultured in some parts of the country especially in the coastal areas. These are eaten by the Filipinos as either lightly-cooked or even raw. The reported occurrence of *Cryptosporidium* in these food sources poses a threat of Cryptosporidiosis among bivalve handlers and consumers in the country since *Cryptosporidium* oocysts can withstand light heating and steaming [42].

Table 2: *Reported prevalence rates of Cryptosporidium infections among animals in the Philippines.*

Year Reported	Animal Population (Location)	*n*	*Cryptosporidium+*	Overall Occurrence Rate	Ref.
1988	Cow (Palawan)	1	1	100.00%	[35]
	Carabao (Palawan)	7	1	14.30%	
2009	Water buffaloes	38	1	2.60%	[43]
2012	Asiatic clams (Aurora)	130	103	79.20%	[40]
2012	Goats (Aurora)	168	30	17.90%	[28]
2013	Asian clams (Laguna)	45	9	20.00%	[41]
2013	Rats (Luzon & Mindoro)	194	50	25.80%	[29]
2016	Bats (Laguna)	45	4	8.90%	[30]
2017	Green mussels in wet markets (Metro Manila)	50	18	36.00%	[3]
2017	Edible bivalves (Manila Bay)	144	67	46.50%	[4]
2018	Dog (Boliwong, Ifugao)	12	4	33.30%	[5]
	Chicken (Boliwong, Ifugao)	6	2	33.30%	
	Goat (Boliwong, Ifugao)	6	1	25.00%	
	Pig (Boliwong, Ifugao)	4	1	25.00%	

Table 3: *Reported occurrence Cryptosporidium among water sources in the Philippines.*

Year Reported	Water Sources (Location)	*n*	*Cryptosporidium* +	Overall Occurrence Rates	Source
2014	River (Pampanga)	3	2	66.70%	[44]
	River (Manila)	3	1	33.30%	
	River (Cavite)	4	2	50.00%	
	Natural lake (Batangas)	6	2	33.30%	
	Swimming pool (Manila)	2	0	0.00%	
	Swimming pool (Cavite)	1	1	100.00%	
	Pond (Pampanga)	1	0	0.00%	
	Pond (Cavite)	3	3	100.00%	
	Rain tank (Cavite)	1	1	100.00%	
	Drinking water	9	0	0.00%	
2016	Metropolitan Waterworks and Sewage System (Luzon)	75	58	77.30%	[8]
2017	Swimming pools (Laguna)	12	12	100.00%	[7]
2018	River (Boliwong, Ifugao)	9	2	22.22%	[5]
	Creek (Boliwong, Ifugao)	9	4	44.44%	
	Water pumps (Boliwong)	6	1	16.6%	

Rats, on the other hand, are common co-inhabitants of humans in the squatter areas of Metro Manila. They are usually seen within the overcrowded households along the stagnant canals where wastes and faecal excreta are customarily thrown by the people in the area. Rats could contaminate the food and the water sources of the human inhabitants due to its access to the household's kitchen and food and water containers.

4.3 Oocyst Contamination in Water

The interests of the Filipino researchers on detecting *Cryptosporidium* in water sources started only in 2014, when some academic institutions in Malaysia had started collaborating with the universities in the Philippines in detecting this protozoan in the South-east Asian region, an epicentre for emerging infectious diseases. *Cryptosporidium* was reported ubiquitous both in the treated and untreated water sources [44]. The reported occurrence of *Cryptosporidium* among water sources in the Philippines is shown in Table 3. An alarming occurrence rate of 77.3% was also reported in a study conducted in Metropolitan Waterworks and Sewage System, a major water source of the majority of Filipinos in Metro Manila and neighbouring provinces [8]. The ubiquity of *Cryptosporidium* in the Philippine

Ryan V. Labana., *Int. Ann. Sci.;* Vol. 6, Issue 1, pp: 18-27, 2019

waters was even established when a study had detected this protozoan in 12 out of 12 examined public swimming pools in Laguna [7]. This data supports the established findings of various studies that *Cryptosporidium* is resistant to chlorination and traditional water treatments [14]. Recently, *Cryptosporidium* was detected in creek, river, and water pumps in an indigenous community situated in the northern part of the country [5]. Based on the occurrence of the oocysts from the three potential reservoirs of *Cryptosporidium*, water remains the main source of the protozoan oocysts that can promote waterborne transmission. It was followed by animals (zoonotic transmission), and humans (human-to-human transmission). These data pose *Cryptosporidium* as a remarkable potential threat against the Philippine public health.

5 Challenges and Possible Solutions

5.1 The Present Condition

In the past years, *Cryptosporidium* detections in the Philippines were usually done among diarrheic patients and minimally among ruminants. Currently, there is increasing number of reported occurrences of *Cryptosporidium* in various water sources in the Philippines. It is evident that this parasite is ubiquitous and is present either in treated and untreated water sources [5-8, 44]. In 2016, it has been established that Metropolitan Waterworks and Sewage System (MWSS) is contaminated with *Cryptosporidium*. It was also reported that the occurrence of this parasite is more pronounced after a heavy rainfall. The presence of this parasite in MWSS is alarming due to its wide range of water distributions within Metro Manila [8]. The factors that have caused parasite contamination in MWSS are not yet studied. Its implications to the public health are also not determined. The cause of parasite contamination and the implications of the contamination need to be elucidated so that water management can be improved the soonest possible time.

Cryptosporidium was also detected both in suburban and in rural areas. This parasite has been reported as contaminants in the swimming pools and other water recreational facilities due to its fecundity and resistance to chlorination. In 2017, some public swimming pools in Laguna were reported harbouring *Cryptosporidium*. These swimming pools are frequently visited both by adults and children. Interestingly, the study has detected a higher parasite contamination in children's pool than the adult's [7]. The cause of this variation was not determined in the study. Children have lower immunity to parasitic infection and the threat of a contaminated pool is alarming. However, there is no follow-up study has been conducted to determine the impact of the contamination to the public health.

This first discoverable study on the epidemiology of *Cryptosporidium* was conducted in an indigenous community inhabited by Tuwali ethno-linguistic group of the Philippines. In the study, *Cryptosporidium* was detected in creek, which is a source of water for paddy fields. This contamination can promote foodborne transmission of infective oocysts to animals and humans. The river in the community was also detected with parasites. The river is used for household chores and for recreational activities in the studied community. In order to identify the risks brought by these contaminations, both animal and human inhabitants in the community were also examined for infection. No direct link was observed between the contamination of creek and river and the prevalence of human cryptosporidiosis in the community but significant risk factors emerged. One of the risk factors was the use of open pit as a toilet facility. Unimproved toilet facility is suspected to contaminate the water system in the community, which in turn infected both the human and animal inhabitants. This poses greater risks of *Cryptosporidium* infection if intervention is not provided by the concerned agencies or institutions. The findings of the study recommended the need for prophylaxis of the entire community in which majority of the inhabitants have no improved toilet facilities [5]. Other recent studies have also reported infection of *Cryptosporidium* among green mussels and edible bivalves, which are both distributed to the public for consumption. Reports on the contamination of *Cryptosporidium* among animal groups and water sources are important but these will remain futile if these do not elucidate the implications to the welfare and health status of the humans with direct contacts to the infected or contaminated sources.

5.2 One Health Approach: Translating Concepts to Practice

One Health is an interdisciplinary response to emerging infectious diseases. One Health Approach has been utilized by many countries as an ideal model for addressing issues on public health and safety including incidences of *Cryptosporidium* infection [45] (Figure 3). The main gap on *Cryptosporidium* information in the Philippines falls on the absence of interlocking ideas among sources of contamination i.e. human, animals, and environment– water sources in particular. For example, the finding on the high occurrence of *Cryptosporidium* in edible bivalves has limited implications in terms of risk managements. One Health recognizes the interconnectivity of all life systems involved in the transmission of the disease particularly those that involve animals (zoonotic). Since *Cryptosporidium* has several animal hosts, it is imperative to examine these hosts, the condition of the environment where they live, and the mechanism on how they infect humans. It provides better understanding on environmental, epidemiological, and etiological factors of *Cryptosporidium* infection not only for better understanding of its biology but also for holistic risk managements [46].

One Health approach requires interdisciplinary collaboration. This means that there is a need to include wide range of expertise to collaborate throughout the study in order to unravel the root cause of the issue [46]. In the case of *Cryptosporidium* contamination in MWSS, various agencies can participate in understanding its causes and effects. The construction designs of dams, for example, can contribute to the cause of contamination which cannot be fully analysed by the experts on parasite but with the aid of the engineering sectors. A survey on hygiene and sanitation practices among industries surrounding MWSS will also provide data for risk factor analysis. Other sectors including social sciences, agriculture, veterinary, community, and other stakeholders may be tapped to answer interconnecting questions while on the process of studying.

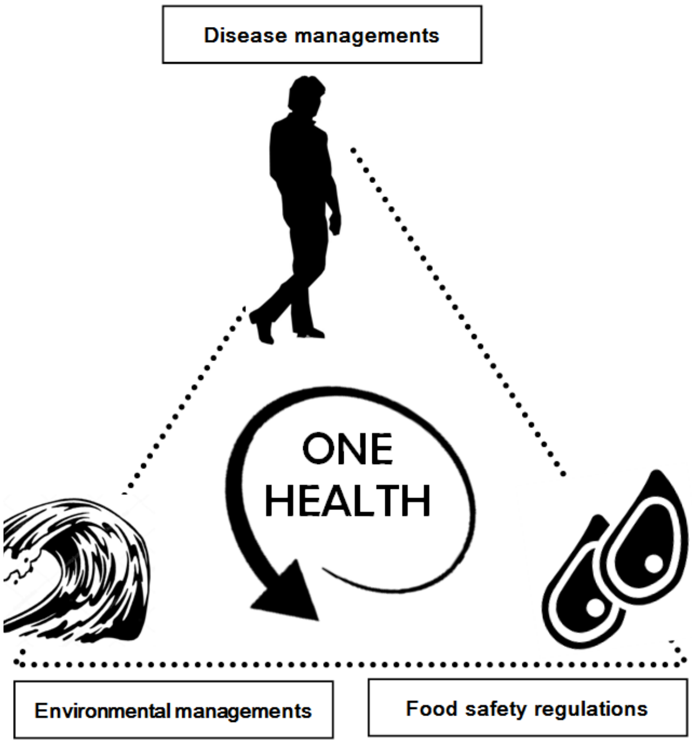

Figure 3: *One Health model with interconnections between the humans, animals, and environment*

The transmission of *Cryptosporidium* infections is very diverse. Majority of the infections are waterborne, but it can also be transmitted via zoonotic and foodborne transmission [6]. Bringing human, animal, and their environment together through the One Health approach is deemed necessary for the upcoming studies in the Philippines to fully understand the future trends and threats of *Cryptosporidium* in the country.

6 Conclusion

There is an increase of waterborne disease incidence reported in the different regions of the Philippines. Their causative agents are constantly unclear, and *Cryptosporidium*, which is known to be a major etiologic agent of waterborne diseases across the globe, was out of the picture in the accessible reports. Based on the collated data in this review, *Cryptosporidium* could be found in the Philippines through its river, natural lakes, swimming pools, ponds, rain tanks, and major dams. It could be transmitted from the Philippine pet and farm animals, from rats, that traverse

Filipino houses and *esteros* or canals, and even from the favourite Filipino cuisines cooked with clams and mussels. *Cryptosporidium* is ubiquitous in the country, but it remains an invisible parasite to the concerns of the Filipino people. One Health is a promising approach in understanding the impact of *Cryptosporidium* contamination to the public health. It requires interdisciplinary collaboration in order to translate its interesting concept to an effective intervention. With the increasing scientific interest on this protozoan in the country, together with the dedications of the Filipino across different sectors, its threat to the public health will soon be fully uncovered.

7 Declaration

7.1 Acknowledgments

The author would like to profusely thank Dr. Julieta Z. Dungca of Centro Escolar University, Philippines, and Dr. Veeranoot Nissapatorn of Walailak University, Thailand, for the intellectual support during the entire review process.

7.2 Funding Source

None

7.3 Competing Interests

None

How to Cite this Article:

R. Labana, "Cryptosporidium in the Philippines", *Int. Ann. Sci.*, vol. 6, no. 1, pp. 18-27, Oct. 2018. Doi: 10.21467/ias.6.1.18-27

References

[1] A. Efstratiou, J.E. Ongerth, P. Karanis, "Waterborne transmission of protozoan parasites: review of worldwide outbreaks – an update 2011-2016," *Water Res* vol. 114, pp. 14-22, May, 2017.

[2] W. Checkley, A.C.C. White, D. Jaganath, M.J. Arrowood, R.M. Chalmers, X-M. Chen, *et al.*, "A review of the global burden, novel diagnostics, therapeutics, and vaccine targets for Cryptosporidium," *The Lancet Infectious Disease* vol. 15, no. 1, pp. 85-94, September, 2014.

[3] L.B.R.O. De la Pena, E.J.A. Pagoso, W.L. Rivera, "Characterization of *Cryptosporidium* isolated from Asia green mussels sold in wet markets of Quezon City, Philippines," *Philipp Agric Scientist* vol. 100, pp. S45-S54, July, 2017.

[4] W.L. Rivera, E.J.A. Pagoso, "*Cryptosporidium* species from common edible bivalves in Manila Bay, Philippines," *Marine Pollution Bulletin* vol. 119, no. 1, pp. 31-39, March, 2017.

[5] R.V. Labana, J.Z. Dungca, V. Nissapatorn. "Community-based surveillance of *Cryptosporidium* in the indigenous community of Boliwong, Philippines, April to December 2017," *Epidemiology and Health,* September, 2018.

[6] D. Carmena, "Waterborne transmission of Cryptosporidium and Giardia: detection, surveillance, and implications for public health," *Current Research, Technology, and Education Topics in Applied Microbiology and Microbial Biotechnology*, 2010.

[7] V.G. Paller, P.M. Kim, M.E. Abadilla, A.M. Bordado, M. Galapon, L.E. Gamalo, *et al.*, "Prevalence of *Cryptosporidium* and *Giardia* in selected recreational pools in Calamba, Laguna, Philippines," *Eco Env & Cons* vol. 23, no. 4, pp. 1945-1951, July, 2017.

[8] F.R. Masangkay, G.D. Milanez, N.E.R. Chua, *et al.*, "Water-borne coccidians in Philippine water sheds: A national inceptive study," *Asian Journal of Biological and Life Sciences* vol. 5, no. 2, pp. 112-119, March, 2016.

[9] A.C. Rola, J.M. Pulhin, R.A. Hall, "Water policy in the Philippines: Issues, initiatives, and prospects," *Zwitzerland: Springer International Publishing*, 2018.

[10] Rappler, "55 die daily in PH from lack of proper sewerage. Rappler, Pasig City, Philippines" Manila, Philippines, https://www.rappler.com/nation/41050-sewage-problem-denr Accessed: 02 February 2018.

[11] L. Xiao, R. Fayer, U. Ryan, S.J. Upton, "*Cryptosporidium* taxonomy: recent advances and implications for public health," *Clin Microbiol Rev* vol. 17, pp. 72-97, January, 2004.

[12] S. Tzipori, H. Ward, "Cryptosporidiosis: biology, pathogenesis and disease," *Microbes Infect* vol. 4, no. 10, pp. 1047-58, August, 2002.

[13] B. J. King, A.R. Keegan, P.T. Monis, C.P. Saint, "Environmental temperature controls *Cryptosporidium* oocyst metabolic rate and associated retention of infectivity," *Appl Environ Microbiol* vol. 71, no. 7, pp. 3848–3857, July, 2005.

[14] T. Slifko, R. Rose, H. Smith, "Emerging parasite zoonoses associated with water and food," *Int J Parasitol* vol. 30, nos. 12-13, pp. 1379-1393, November, 2000.

[15] R.A. Dillingham, A.A. Lima, R.L. Guerrant, "Cryptosporidiosis: Epidemiology and impact," *Microbes Infect* vol. 4, pp.1059–66, August, 2002.

[16] V.A. Cama, C. Bern, J. Roberts, L. Cabrera, C.R. Sterling, Y. Ortega, R.H. Gilman, L. Xiao, "Cryptosporidium Species and Subtypes and Clinical Manifestations in Children, Peru," *Emerging Infectious Diseases* vol. 14, no. 10, pp. 567-1574, October, 2008.

[17] M. Bouzid, P.R. Hunter, R.M. Chalmers, K.M. Tyler. "*Cryptosporidium* pathogenicity and virulence," *Clin Microbiol Rev* vol. 26, pp. 115–34, January, 2013.

[18] P. Karanis, K. Kourenti, H.V. Smith, "Waterborne transmission of protozoan parasites: a worldwide review of outbreaks and lesson learnt," *J Water Health* vol. 5, pp. 1-38, March, 2007.

[19] S. Baldursson, P. Karanis, "Waterborne transmission of protozoan parasites: review of worldwide outbreaks – an update 2004-2010," *Water Res* vol. 6, no. 20, pp. 6603-6614, December, 2011.

[20] V. Dietz, D. Vugia, R. Nelson, *et al.*, "Active, multisite, laboratory-based surveillance for *Cryptosporidium parvum," Am J Trop Med Hyg* vol. 62, no. 3, pp. 368-372, March, 2000.

[21] Y. Lim, V. Nissapatorn, "Transmission of waterborne parasites in the Association of Southeast Asian Nations (ASEAN): overview and directions forward," *Food and Waterborne Parasitology,* December, 2017.

[22] J.H. Cross, A. Alcantara, A. Alquiza, G. Zaraspe, C. Ranoa, "Cryptosporidiosis in Philippine children," *Southeast Asian J Trop Med Public Health* vol. 16, no. 2, pp. 257-260, June, 1985.

[23] W.L. Rivera, J.A.D.L. Yason, P.T. Rivera, "Serological detection of Cryptosporidiosis among Filipino cancer patients," *Parasitol Res* vol. 98, pp. 75-76, October, 2005.

[24] F.G. Claveria, C. Alonzo, A.M. Bacal, Z.M. Mayugba, "Survey of Cryptosporidium sp. Infection in two impoverished communities in Metro Manila, Philippines," *J Protozool Res* vol. 17, pp. 32-38, December, 2007.

[25] F.F. Natividad, C.C. Buerano, C.B. Lago, C.A. Mapua, B.B. de Guzman, E.B. Seraspe, *et al.*, *"*Prevalence rates of Giardia and *Cryptosporidium* among diarrheic patients in the Philippines," *Southeast Asian J Trop Med Public Health* vol. 39, no. 6, pp. 991-999, November, 2008.

[26] W.L. Rivera, J.A.D.L. Yason, "Molecular detection of *Cryptosporidium* from animal hosts in the Philippines," *The Philippine Agricultural Scientist* vol. 91, no. 4, pp. 473-477, 2008.

[27] B.E. Omoruyi, U.U. Nwodo, C.S. Udem, F.O. Okonkwo, "Comparative diagnostic techniques for *Cryptosporidium* infection," *Molecules* vol. 19, no. 2, pp. 2674-2683, February, 2014.

[28] C.Y.J. Domingo, R.D.C. Ador-Dionision, G.C. Lanzanida, R.M. Corales, "Human and caprine cryptosporidiosis among smallhold farms in Aurora province, Philippines," *Philipp J Vet Anim Sci* vol. 38, no. 1, pp. 53-62, 2012

[29] J.S.Y. Ng-Hublin, G.R. Singleton, U. Ryan, "Molecular characterization of *Cryptosporidium* spp. from wild rats and mice from rural communities in the Philippines," *Infection, Genetic and Evolution* vol. 16, pp. 5-12, June, 2013.

[30] F. Murakoshi, F.C. Recuenco, T. Omatsu, *et al.*, "Detection and molecular characterization of *Cryptosporidium* and *Eimeria* species in Philippine bats," *Parasitol Res*, May, 2016.

[31] M.T. Katanik, S.K. Schneider, J.E. Rosenblatt, G.S. Hall, G.W. Procop, "Evaluation of Color PAC Giardia/*Cryptosporidium* rapid assay and ProsPecTGiardia/*Cryptosporidium* microplate assay for detection of Giardia and *Cryptosporidium* in fecal specimens," *J Clin Microbiol* vol. 39, pp. 4523-4525, December, 2001.

[32] J.R. Limor, A.A. Lal, L. Xiao, "Detection and differentiation of *Cryptosporidium* parasites that are pathogenic for humans by real-time PCR," *J ClinMicrobiol* vol. 40, pp. 2335–8, July, 2002.

[33] J.A. Higgins, R. Fayer, J.M. Trout, L. Xiao, A.A. Lal, S. Kerby, "Real-time PCR for the detection of *Cryptosporidium parvum*" *J Microbiol Methods* vol. 47, pp. 323–37, December, 2001.

[34] J. Cross, A. Alcantara, L. Alquiza, G. Zaraspe, C. Ranoa, "Cryptosporidiosis in Philippine children," *Southeast Asian J. Trop. Med. Publ. Hlth*, vol. 16, no. 2, pp. 257-260, 1985.

[35] M.A. Laxer, A.K. Alcantara, M. Javato-Laxer, M.D. Cui, R.A. Leano, S. Bautista, N. Ramilo, *et al.*, "*Cryptosporidium* from Palawan, Republic of the Philippines," *The Philippine Journal of Microbiology and Infectious Disease* vol. 17, no. 1, pp. 1-3, 1988.

[36] J.H. Cross, G. Zaraspe, L. Alquiza, C. Ranoa, "Intestinal parasites in some patients seen at San Lazaro Hospital, Manila, Philippines," *Phil J Micbiol Infect Dis* vol. 18, no.1, pp. 25-27, 1989.

[37] M.A. Laxer, A.K. Alcantara, M. Javato-Laxer, D.M. Menorca, M.T. Fernando, C.P. Ranoa, "Immune response to Cryptosporidiosis in Philippine children," *Am J Trop Med Hyg* vol. 42, no. 2, pp. 131-139, 1990.

[38] E. Paje-Villar, B.G. Co, E.H. Caradang, A. Raymundo, E. Lagamayo, E. Lavadia, E. Rigor, C.A. Hart, "Non-bacterial diarrhoea in children in the Philippines," *Ann Trop Med Parasitol* vol. 88, no. 1, pp. 53-8, February, 1994.

[39] J.M.S. Velasco, I-K. Yoon, C.J. Mason, R.G. Jarman, "Applications of PCR (Real-Time and MassTag) and Enzyme-Linked Immunosorbent Assay in diagnosis of respiratory infections and diarrheal illness among deployed U.S. military personnel during Exercise Balikatan 2009, Philippines" *Military Medicine* vol. 176, no. 10, pp. 1096-1100, October, 2011.

[40] C.Y.J. Domingo, P. Casao, B. Asuncion, "*Cryptosporidium* oocysts (Apicomplexa: Cryptosporidiidae) in the freshwater Asiatic clam, *Corbicula fluminea* O. F. Müller, 1774 (Bivalvia: Corbiculidae) from selected municipalities of Aurora, Philippines," *Phillip J Vet Med* vol. 49, no. 2, pp. 83-87, 2012.

[41] V.G. Paller, R.L. Salumbre, C.P.P. dela Cruz, "Asian clams as bio-indicator of *Cryptosporidium* contamination in Laguna de Bay," *Eco Env & Cons* vol. 19, no. 3, pp. 635-642, 2013.

[42] J. Hohweyer, A. Dumetre, D. Aubert, N. Azas, I, Villena, "Tools and methods for detecting and characterizing Giardia, *Cryptosporidium*, and *Toxoplasma* parasites in marine molluscs" *J Food Prot* vol. 76, pp. 1649-1657, September, 2013.

[43] M. Villanueva, C. Domingo, N. Abes, C. Mingala, "Incidence and risk factors of *Cryptosporidium* spp. infection in Water Buffaloes confined in a communal management system in the Philippines" *The Internet Journal of Veterinary Medicine* vol. 8, no. 1, pp. 1-7, 2009.

[44] S. Onichandran, T. Kumar, C.C. Salibay, *et al.*, "Waterborne parasites: a current status from the Philippines," *Parasit Vectors* vol. 7, pp. 244, May, 2014.

[45] T.P. Monath, L.H. Kahn, B. Kaplan, "Introduction: One Health Perspective" *ILAR Journal* vol. 51, no. 3, pp. 193-198, 2010.

[46] P.A. Conrad, L.A. Meek, J Dumit, "Operationalizing a One Health approach to global health challenges" Comparative Immunology, Microbiology, and Infectious Diseases vol. 36, pp. 211-216, 2013.