CHAPTER II

LITERATURE REVIEW

2.1 SOIL-TRANSMITTED HELMINTHIASIS

Of the 100 species of helminths reported from the human intestinal tract, the nematodes such as *A. lumbricoides*, hookworm and *T. trichiura* are the most common species (Cheesbrough, 2005). It is estimated that at least one third of the world's population is chronically affected by intestinal parasites and the prevalence of infections varies from one country to another and sometimes from one area to another in the same country (WHO, 2006). The public health importance of intestinal helminth infections continues due to their effects on both the nutritional and the immune status of infected individuals, particularly those living in the tropical and subtropical areas. Intestinal helminthic infections mainly affect the physical and mental development of children who are the most vulnerable. The prevention and control of these parasites are mainly by mass drug distribution. However, chemotherapy alone does not solve the problems, and the role of other measures such as sanitation and health education should also be considered. The success or failure of control measures may depend mainly on man's behavioral attitude and practices. Therefore, the participation of the community in active programme directed towards the improvement of their health and standard of living is of significant importance (WHO, 2006).

Soil-transmitted helminth (STH), a group of NTDs commonly known as intestinal worms, are parasites that serve as major contributors to morbidity or disease incidence in the developing countries. The causal agent of STH is any of the following worms: *Ascaris lumbricoides*, *Trichuris trichiura* and the hookworms. Infection is caused by the ingestion of eggs in contaminated food or water (*A. lumbricoides* and *T. trichiura*) or via penetration of the skin by larvae in the soil (hookworms). Infections by *A. lumbricoides* and *T. trichiura* usually have their maximum intensity at the age of 5-10 years, while the maximum intensity of hookworm infection is at the age of 20-25 years (Stephenson, 1987). Despite the low cost of treatment (i.e., standard drugs costing less than $0.05 per course), many developing countries have not mobilized resources and institutions to achieve a high coverage rate of deworming (WHO, 2006). For instance, WHO report showed that Bangladesh, India, Indonesia, and Thailand all had national coverage of treatment for school-age children below 25%, with coverage in Thailand lower than 1% (WHO, 2012). Significant associations of STH infections with malnutrition, VAD, IDA and poor cognitive and educational performance have been reported in several previous studies especially among children in rural areas (Ahmed *et al.*, 2012; Al-Mekhlafi *et al.*, 2005a; Dreyfuss *et al.*, 2000; Nokes and Bundy, 1994).

2.1.1 The Parasites

Ascaris lumbricoides (common roundworm) *T. trichiura* (whipworm) *Ancylostoma duodenale*, *Necator americanus* (hookworms) and *Strongyloides stercoralis* (threadworm) are STH species. *A. lumbricoides*, *S. stercoralis* and hookworms live inside the human small intestine while *T. trichiura* lives in the cecum for one to several years. They are known as STH because eggs/larvae passed in feces need about 2-3 weeks to mature in the soil before they become infective. This study will focus on the three main STH species, *A. lumbricoides*, *T. trichiura* and hookworms. The biological characteristics of these worms are summarized in Table 2.1. Generally, STH exist primarily in sandy or loamy soil and cannot live in clay or muck. They need warm soil where temperatures are over 18°C and the annual rainfall averages must be more than 1000 mm. It was reported that areas with wet climates exhibit increased transmission and marked seasonality (Cooper *et al.*, 1995).

TABLE 2.1: Characteristics of the adult worms of 3 main STH species. (Source: Brooker *et al.*, 2006; Cooper *et al.*, 1995)

Characteristics	***T. trichiura***	***A. lumbricoides***	**Hookworm (*N. americanus* and *A. duodenale*)**
Length (mm)	30-50	150-400	8-13
Location in host	Cecum	Jejunum	Duodenum, jejunum
Infective stage	Ova	Ova	larva
Egg output (eggs/female worm/day)	2,000-20,000	Up to 200,000	10,000-30,000
Life expectancy of infective stages	10-30 days	28-84 days	3-14 days
Adult life span in a host	1-2 years	1-2 years	3-4 years
Pre-patency (Period for adult development to sexual maturity)	50-84 days	50-80 days	28-50 days
Larvae development time to infective stage	20-100 days	8-37 days	2-14 days
Maximum temperature for viable development	37-39°C	35-39°C	40°C

I. *Trichuris trichiura* (whipworm)

Trichuris trichiura is a nematode belonging to the family *Trichuroidea* and it causes a parasitic disease called trichuriasis. The adult worm is pinkish-white in colour. Its whip-like shape refers to the posterior part containing the reproductive organs and intestine of the parasite. The female is about 35-50 mm and is longer than the male by 5 mm. The adult female produces thousands of eggs reaching to 20,000 eggs per day (Cooper, 1995). The cecum is the ideal site of the large intestine for invasion, and infection reaches to rectum in heavy infection (Hotez, 2000).

Transmission to humans occurs by the ingestion of the embryonated eggs which release larvae that burrow into the colonic epithelia when reaching the cecum where they develop into adult worms. The anterior portion of the adult parasite becomes embedded in epithelial tunnels it creates by secreting pore forming proteins (Drake *et al.,* 1994), Inflammation at the site of attachment results both from disruption of the normal colonic texture as well as macrophages and proinflammatory cytokines in the lamina propria (MacDonald *et al.,* 1994). The adult life span of *Trichuirs* worm is 1-2 years, and the development time to the infective egg is 20-100 days. While the development period from ingested egg to adult worm takes about 8-12 weeks. The life cycle of *T. trichiura* is illustrated in Figure 2.1.

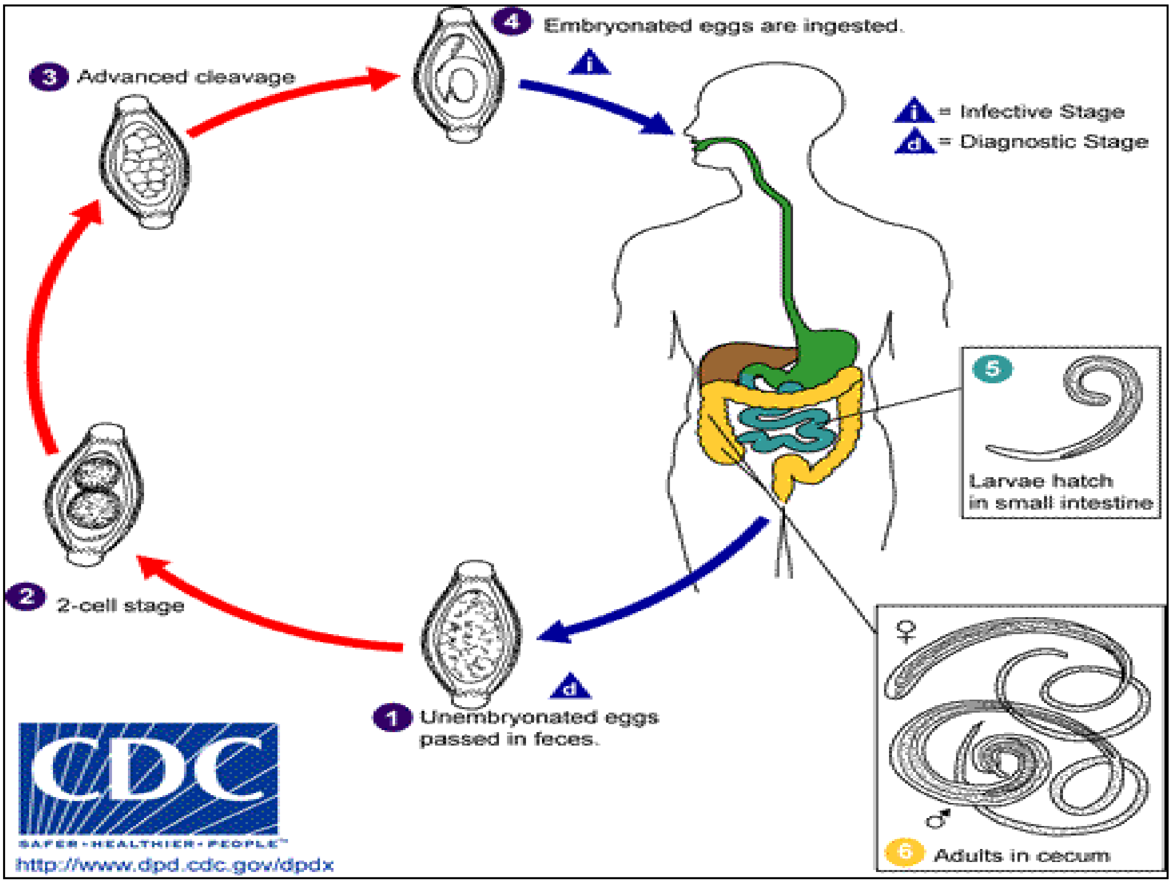

FIGURE 2.1: *Trichuris trichiura* life cycle

(Source: with permission, Centres for Disease Control and Prevention, Georgia, USA)

II. *Ascaris lumbricoides* (common roundworm)

Ascaris, a member of the family *Ascarididae*, is the first agent of infection described in humans (Crompton, 1989a). The adult stage of *A. lumbricoides* is a cylindrical creamy white or pinkish worm with the male being smaller (12–25 cm) than the female (20–40 cm). The adult worm lives in the jejunum with its anterior end facing the direction of the intestinal flow (Makidono, 1956). The mature female worm produces 100,000–200,000 eggs per day. Eggs excreted in feces need a period of maturation in soil. Under good environment, of warm, moist soils, the embryo develop within the eggshell. The eggs need from 2 to several weeks in the soil for the development process into infective egg. The larvae that emerge from ingested eggs in the jejunum penetrate the intestinal wall and migrate through the hepatic venules to the right side of pulmonary circulation where they break into alveolar spaces and undergo further moults. From the alveoli, the 1.5 mm long larvae ascend to the trachea, and are swallowed, undergo a last moult in the intestine, and develop to adults. From the ingestion of infective eggs to the production of eggs by mature adult worms, takes about 8–12 weeks. The adult worm has a life span of about 1-2 years (Hotez *et al.*, 2003). The life cycle of *A. lumbricoides* is illustrated in Figure 2.2.

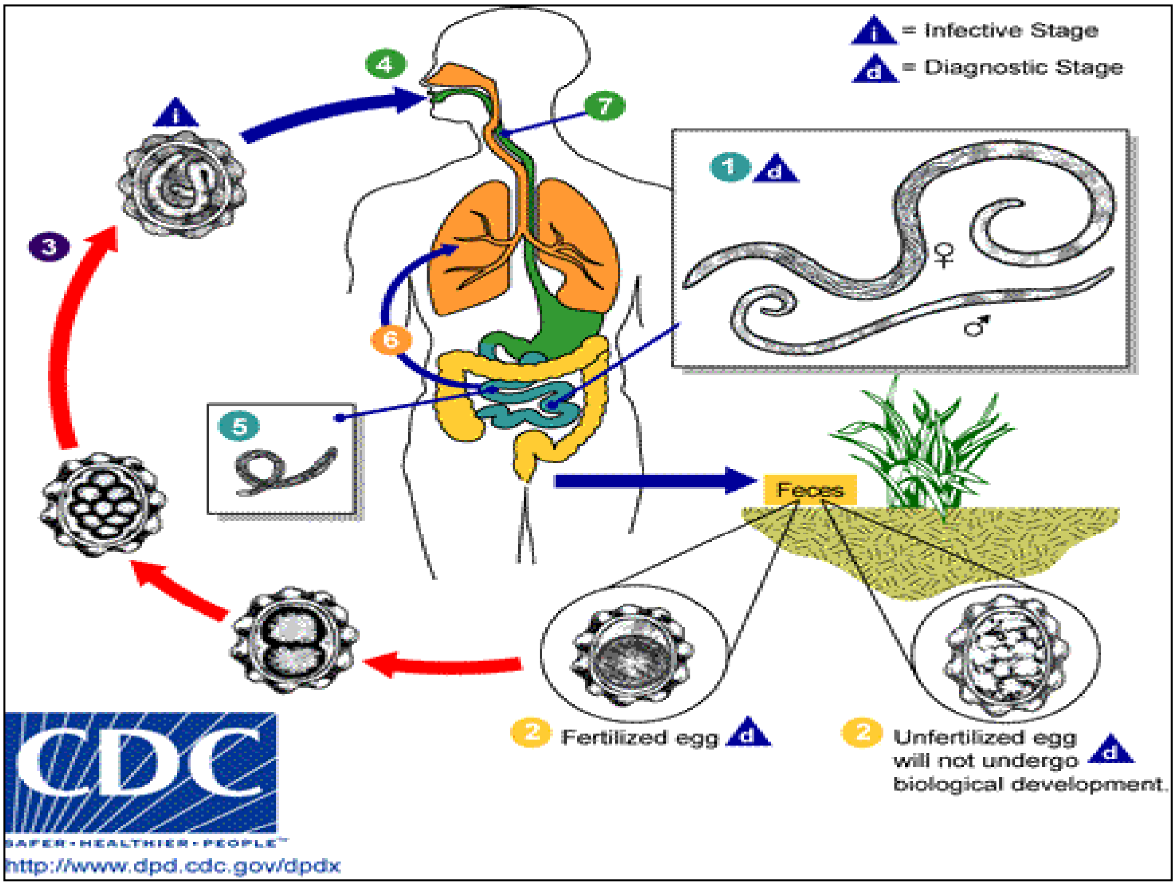

FIGURE 2.2: *Ascaris lumbricoides* life cycle
(Source: with permission, Centres for Disease Control and Prevention, Georgia, USA)

III. Hookworms

Hookworms are nematodes belonging to the family *Ancylostomatidae*, a part of the superfamily *Strongyloidea*. *Necator* and *Ancylostoma* are the two major genera that infect humans and are characterized by the presence of oral cutting organs (teeth or cutting plates) in the adult stages (Hotez, 1995a). Human hookworm infection is caused by either *N. americanus* or *A. duodenale*. The adult worm is small, cylindrical and grayish in color with the female being larger than male; 10-13 mm, 8-11 mm, respectively. The eggs are released in feces hatch in soil within 24-48 hours into rhabditiform or non-infective stages which subsequently mature into infective filariform larvae (L3 larvae) which can survive in the soil up to 2 weeks without finding a host.

The larvae are able to penetrate the skin of the foot, and once inside the body, they migrate through the blood circulation to the lungs and then migrate up to the trachea, and are swallowed and reach the small intestine, where the larvae mature into adults. It takes about 5-9 weeks period from skin penetration until the development of an adult worm. The adult worm has a life span of about 3-4 years (Booker *et al.*, 2006). There are significant biological and bio-pathological differences between the two main genera of hookworm. Whilst *A. duodenale* has two pairs of sharp teeth, *N. americanus* has a pair of cutting plates in the buccal capsule. Unlike *N. americanus*, which can complete its life cycle in humans only after skin penetration, *A. duodenale* has been reported to be transmitted by oral ingestion of the larvae (Hotez *et al.*, 2005). Moreover, *A. duodenale* is longer than *N. americanus*, produces more eggs (*A. duodenale* 25,000-30,000 eggs/day vs *N. americanus* 9,000-10,000 eggs/day), and higher virulence as it causes greater blood loss (Albonico *et al.*, 1998). The life cycle of hookworms is illustrated in Figure 2.3.

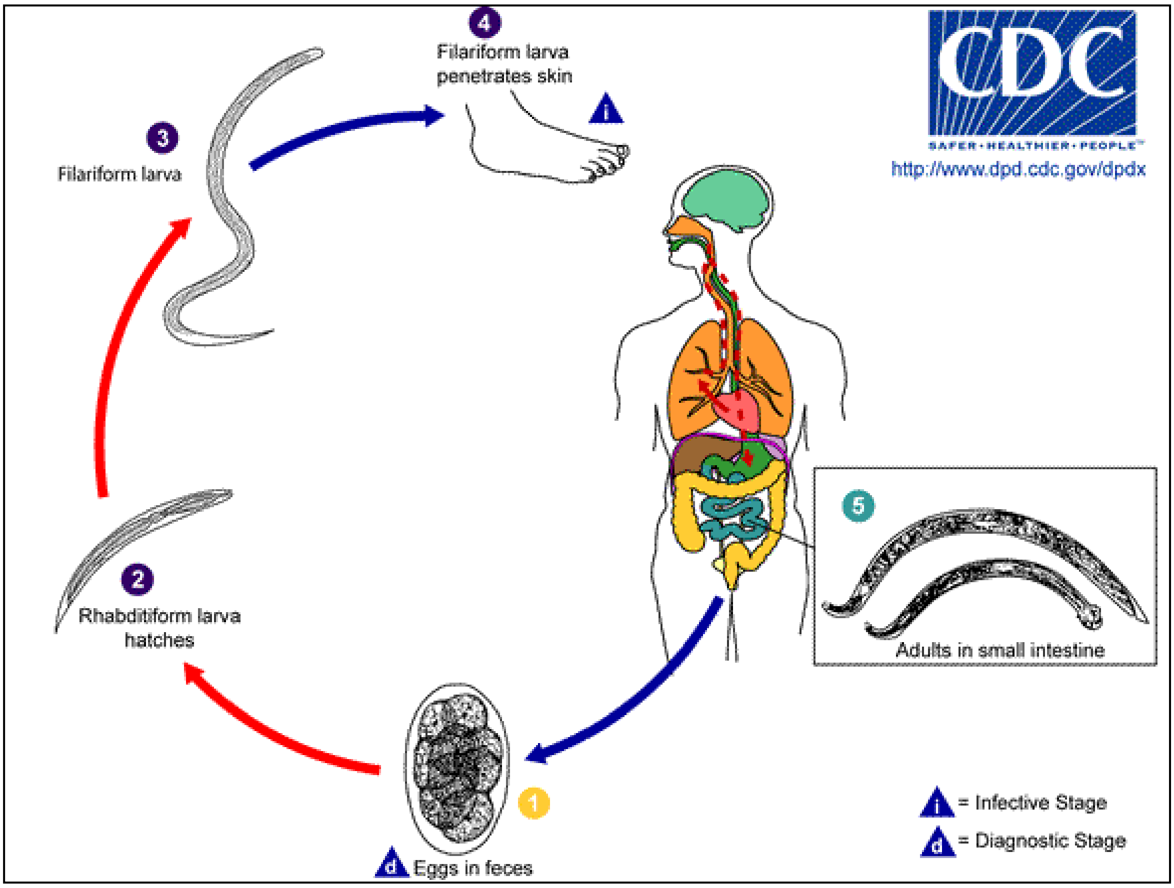

FIGURE 2.3: Hookworm life cycle

(Source: with permission, Centres for Disease Control and Prevention, Georgia, USA)

2.1.2 Clinical manifestations of STH infections

The disease caused by the main STH species is called soil-transmitted helminthiasis or STH infections. The clinical manifestations of STH infections differ according to the species. Moreover, the clinical manifestations of STH infections are proportional to the intensity of infection. Light intensity is usually asymptomatic while moderate-to-heavy infections are associated with severe complications (Neva and Brown, 1994). The clinical features of STH infections are classified into the acute sign and symptoms associated with early larval migration through the skin and viscera, and the chronic symptoms resulting from parasitism of the gastrointestinal tract by the adult worms.

i. Early larva migration

Many tissue reactions can occur during the early migration of *Ascaris* and hookworm larvae to the lungs. The larvae can provoke an inflammatory reaction consisting of eosinophilic granuloma (accumulation of eosinophils in the lung in response to *Ascaris* infection) associated with fever, a non-productive cough, wheezing, dyspnoea, and with blood in the sputum produced during severe illness. These symptoms are described as Loeffler's syndrome in which *Ascaris* remains the most common cause worldwide particularly among children (Joob and Wiwanitkit, 2012).

As for hookworm infections, repeated exposures to *N. americanus* and *A. duodenale* filariform larvae result in ground itch, a local papular rash and pruritus on the hands and feet (Hotez *et al.,* 2004). Similar to *Ascaris*, third-stage larvae migrate to the lungs and cause Loeffler's syndrome in which the resulting pneumonitis is not as severe as in *Ascaris* infection (Neva and Brown, 1994). Moreover, oral ingestion of *A. duodenale* larvae can result in Wakana syndrome, which is characterised by pharyngeal irritation, cough, vomiting, and dyspnea (Brooker *et al.*, 2004; Hotez *et al.*, 2004).

ii. Intestinal parasitism by adult worm

During the intestinal late phase of *Ascaris* infection, gastrointestinal symptoms can occur due to the presence of a large numbers of adult *Ascaris* in the small intestine. These involve abdominal pain and distension, lactose intolerance, and malabsorption of vitamin A (Taren *et al.,* 1987).

With regard to *Trichuris*, the adult worm is usually found partially embedded in the mucosa by the anterior end, while the posterior end lies free in the lumen of the large intestine. These adult worms can be seen in the colon and rectum in case of heavy infections and can cause colitis. It produces a clinical picture that resembles inflammatory bowel disease, including chronic abdominal pain, tiredness and diarrhea (sometimes bloody diarrhea) (Bundy and cooper, 1989).

For hookworm, the symptoms are associated with intestinal inflammation stimulated by feeding hookworms which bite the intestinal mucosa and suck blood voraciously producing anticoagulant during their feeding, which allows bleeding to continue (Blanton, 2007). Based on the intensity of infection, the symptoms vary from nausea, abdominal pain and intermittent diarrhea which may contain blood to progressive anemia in chronic cases (Hotez, 2004). Moreover, intense chronic infections associated with gross intestinal blood loss and hypoproteinimia may cause palpitations, pallor of the mucous membranes, fatigue and weakness, shortness of breath, hemorrhages and edema. The presence of more than 40 adult worms in the small intestine is estimated to be sufficient to cause anemia and reduce host hemoglobin concentration below 11 g/dl (Albonico *et al.*, 2004). It was reported that hookworm infections can drain nearly 50 ml of blood per day when the egg per gram (epg) feces is about 250 thereby decreasing the red blood cell count, hemoglobin and serum proteins (Nallam and Gnanamani 1998).

iii. Complications of STH infections

STH infections are usually asymptomatic particularly when the intensity of infection is light. However, pre-school children, school-age children and women of child-bearing age are at higher risk of prominent morbidity by STH infections (WHO, 2011). Moreover, the complications of STH infections are associated with moderate-to-heavy infections. For instance, the adult worms of *Ascaris* can form a mass in the lumen of ilium leading to intussusception, partial or complete obstruction, intestinal perforation and peritonitis which can be fatal due to septicemia and toxic effect of peritonitis (Khuroo *et al.*, 1996; Villamizar *et al.*, 1996). Moreover, the adult worms can enter the lumen of the appendix leading to acute appendicitis. In addition, ectopic migration of the adult worms can cause cholecystitis, pancreatitis and hepatic abscess (Khuroo *et al.*, 1990).

Similarly, heavy infection with whipworm causes a serious complication syndrome called *Trichuris* Dysentery Syndrome (TDS). Children with TDS suffer from rectal bleeding, diarrhoea, prolapsed rectum and clubbing of the fingers (Saldiva *et al.*, 1999). Heavy trichuriasis may also lead to growth deficits in children, IDA, intellectual and cognitive impairments and poor school performance (Shin *et al.*, 2004; Savioli, 2004; Saldiva *et al.*, 1999; Stephenson *et al.*, 1993). Likewise, blood loss in severe hookworm infections can lead to severe IDA especially among children and pregnant women (Savioli, 2004; Dreyfuss *et al.*, 2000). The severe IDA caused by hookworm infection during pregnancy can have adverse effects on the mother, fetus, and the neonate (Christian *et al.*, 2004).

Furthermore, the effects of STH infections may continue to the adulthood. For instance, hookworm-IDA can cause decrease physical fitness, shortens working life and reduces working capacity of infected individuals (Hotez *et al.*, 2009; Bleakley, 2007). Similarly, the negative impact of STH infections on the cognitive function and school performance in children may have longer effect in their productivity in adulthood (Bundy, 1997b). Moreover, the devastating impact of STH infections may affect the economic productivity and trap endemic communities in a cycle of poverty, underdevelopment and disease (Hotez *et al.*, 2009; Bleakley, 2007; Haddad and Bouis, 1991). The negative impacts of STH infections on children and adults are illustrated in Figure 2.4.

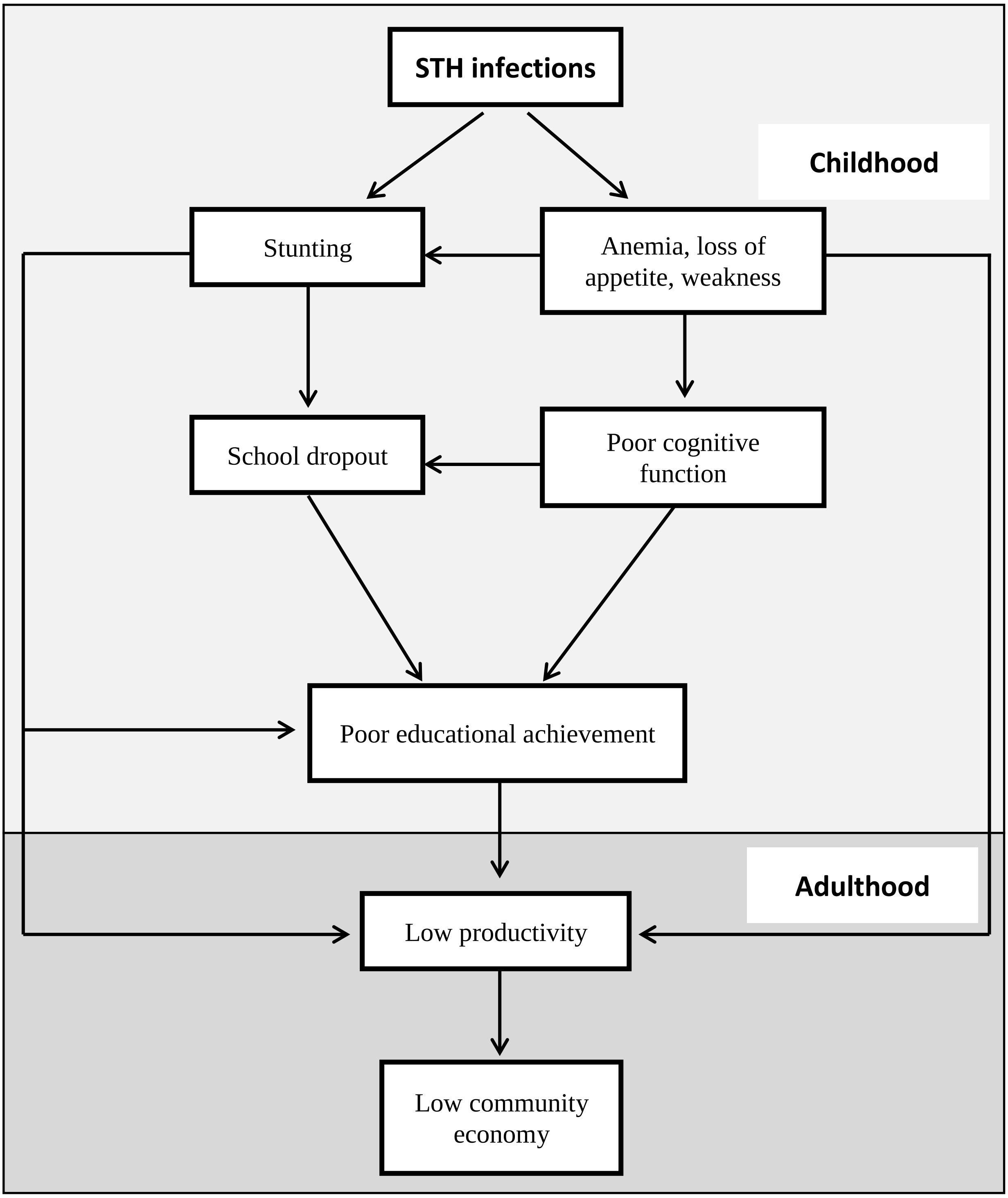

FIGURE 2.4: The impact of STH infectios in humans during childhood and adulthood.

2.1.3 Laboratory diagnosis of STH infections

The laboratory diagnosis of STH infections is done by the detection of their characteristic eggs and/or larvae in stool samples collected from infected individuals. The following are some techniques which are commonly used for stool examination to detect STH eggs and larvae:

i. **Direct smear technique:** It should be performed on every stool samples received in the lab. The motile larvae of *Strongyloides* or hookworm can be detected as well as the eggs of other species.

ii. **Formalin-ether sedimentation technique:** It is the method of choice for all intestinal parasitic infections including STH especially in light infections. The method involves using formalin which is a fixative reagent and prevents any further development of the stages.

iii. **Kato-Katz technique:** It is the gold standard technique recommended by the WHO for the diagnosis of STH infections. It is very useful in egg counting in order to evaluate the intensity of infections (WHO, 2002). In this technique, cellophane tape soaked in malachite green solution is used as a clearing agent (Odongo-Aginya *et al.*, 2007). A known size of fecal material is used and the eggs in the whole slide are to be counted.

iv. **McMaster technique:** It is used for detecting and counting STH eggs in fecal samples. Egg counting is done using a counting chamber which enables a known volume of fecal suspension to be examined microscopically (Barda *et al.*, 2014).

v. **FLOTAC technique:** It has been recently developed as an innovative direct method for the diagnosis of intestinal parasitic infections. In this method, a cylindrical device with two 5-ml flotation chambers (FLOTAC apparatus) which enables up to 1 g of stool to be prepared for microscopic examination. This technique is useful as it can be used on fresh or preserved fecal samples (Knopp *et al.*, 2009).

vi. **Harada Mori culture:** Small amount of feces is incubated on a filter paper strip in a test tube containing water for the purpose of culturing and recovering nematode larvae of hookworms and *Strongyloides*. This method is useful in detecting light hookworm infections (Jozefzoon and Oostburg, 1994).

2.1.4 Treatment of STH infections

Nowadays, some drugs are widely used for the treatment of STH infections with albendazole and mebendazole being most commonly used. These drugs are safe, cheap, and active against these parasites with some consideration to be taken when treating pregnant women and children aged below 2 years (WHO, 2005). The most widely used drugs are:

i. **Albendazole:** It is a broad-spectrum anthelmintic agent which is given as a single dose of 400 mg, reduced to 200 mg for children below 24 months. This single dose is highly effective against ascariasis and hookworm infections while *Strongyloides* and *Trichuris* infections may require more doses such as a 3-day course of treatment (WHO, 1999; Al-Mekhlafi *et al.*, 2008b). Basically, albendazole prevents the formation of microtubules by binding to the worm β-tubulin and inhibits the parasite microtubule polymerisation which causes death of adult worms within few days (Bethony *et al.*, 2006). The drug is poorly absorbed by the host and most of its anthelminthic action operates directly in the gut. Hence, albendazole and other benzimidazole derivatives do not kill immature worms and cannot prevent the re-infection which can occur soon after treatment (Jia *et al.*, 2012).

ii. **Mebendazole:** It is also a benzimidazole derivative which is available as flavored chewable tablets (100 and 500 mg), and as an oral suspension (100 mg/5 ml). Similar to albendazole, mebendazole is given as a single dose which is effective against *Ascaris* and hookworm infections while in trichuriasis, a 3-day course of treatment should be used (Stuckler *et al.*, 2011). The drug is very insoluble in water and is poorly absorbed from the gastrointestinal tract and this limits its effect to the worms in the gut only.

iii. **Other drugs:** Levamisole and pyrantel pamoate are also given as a single dose. They are effective against STH infections. Pyrantel pamoate is less effective against hookworm infections but highly effective against trichuriasis (WHO, 1999).

Many studies have shown a low efficacy against anthelmintics. For instance, albendazole (400 mg) as a single dose is the drug of choice for *Ascaris* and hookworm infections and has a high cure rate, but the cure rate for *Trichuris* infection was low (Al-Mekhlafi *et al.*, 2008a; Horton, 2000; Norhayati *et al.*, 1997b). The low efficacy of the treatment against *Trichuris* could be attributed to the adult worms being embedded in the mucosa of the large intestine. A previous study in Mexico showed that the efficacy of albendazole against *Ascaris* was 100%, but it was only 35% against *Trichuris* (Rodriguez-Perez, 2011). Another study in Lao PDR found that the cure rate of hookworm infection was 36% by albendazole and 18% by mebendazole (Soukhathammavong *et al.*, 2012). Similar problem has been reported with pyrantel-oxantel for the treatment of trichuriasis and the cure rate was 32% (Albonico *et al.*, 2002). Likewise, a study in Zanzibar, Tanzania, showed that the efficacy of the mebendazole or albendazole alone against trichuriasis was very poor with cure rates of 19% and 10%, respectively (Knopp *et al.*, 2010).

In Malaysia, the resistance of hookworm infections to pyrantel pamoate was reported during the 1970s and resulted in the termination of the national mass deworming programme (Ahmed *et al.,* 2011). Previous studies have reported similar low efficacy of albendazole tablets in treating trichuriasis among Orang Asli communities (Al-Mekhlafi *et al.,* 2008a; Norhayati *et al.,* 1997b).

2.1.5 Risk factors of STH infections

Several previous studies have identified numerous risk factors which are associated with the high prevalence and intensity of STH. These include some demographic, socioeconomic, environmental and behavioral factors which form a web of causation for STH infections (Figure 2.5). Hence, a better understanding of the relationship of risk factors to the dynamics of transmission of STH is essential to implement effective control measures. The risk factors of STH infections may differ from one region to another and sometimes within the population or the country itself (de Silva *et al.,* 2003). The risk factors of STH infections are discussed briefly.

i. Environmental factors

The environmental conditions in the unplanned slums of developing countries are ideal for the persistence of STH infections. Many studies have shown a high prevalence of these infections in children of slums and shanty towns (Crompton and Savioli, 1993).

Both *Ascaris* and *Trichuris* commonly occur in semi urban environments and in rural areas (Phiri *et al.,* 2000). In contrast, high prevalence of hookworm infection is restricted to areas where rural poverty prevails (Albonico *et al.,* 1997). Viable *Ascaris* and *Trichuris* eggs have been recovered from soil samples of more than 10 years (Crompton, 1989a). The ascaroside lipid layer of *Ascaris* eggs are coated with a mucopolysacccharide that can adhere to a wide variety of environmental surfaces; door handles, dust, fruits and vegetables and money (Crompton, 1989a).

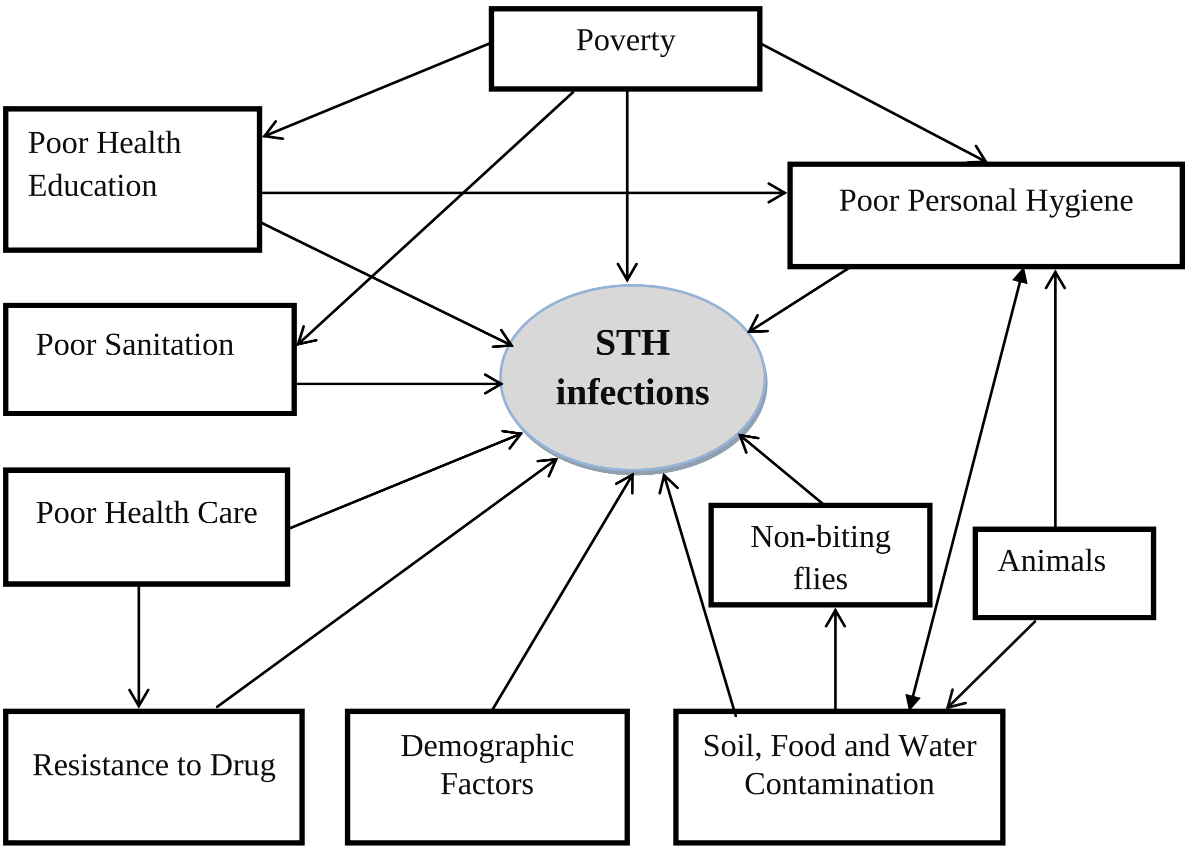

FIGURE 2.5: Risk factors of STH infections (the web of causation).

A. Soil

Soil is an essential element for the development of STH. The eggs must reach the proper soil where they develop into the infective stages. The most suitable soil should be moist and loamy while clay soils are believed to prevent egg development (Mizgajska, 1993). *Ascaris* eggs develop best in less permeable clay soils, and the eggs are vulnerable to direct sunlight; thus survivability increases with soil depth. On the other hand, hookworm eggs hatch in the soil to produce the rhabditiform larvae (L1) which molt twice to the infective filariform larvae (L3). Egg development in the soil is dependent upon a number of factors including optimal temperature, adequate shade and moisture (Crompton, 1989a).

B. Climate and season

Ascaris eggs do not embryonate at low humidity and with atmospheric saturation less than 80%. Tropical conditions would normally result in high endemicity (Brooker and Michael, 2000). For hookworm, moisture is crucial to allow L3 larvae to move vertically in the soil, particularly at night (Crompton, 1989b).

Adequate warmth and moisture are key features for each of the STH. *Ascaris* and *Trichuris* eggs have shells which are thicker than hookworm eggs, and therefore survive drier climates better. However, the rates of infection are low in dry climates for all STH species. It has been concluded that total rainfall and its seasonal distribution may explain the observed patterns of infection; wetter areas are usually associated with increased transmission of all three major STH infections (Brooker and Michael, 2000).

Previous studies from West Africa suggest that a minimum of 1400 mm annual rainfall is necessary for the prevalence of *A. lumbricoides* to exceed 10% (Brooker and Michael, 2000). Similarly, a study in Cameroon, Chad and Uganda suggests that *A. lumbricoides* and *T. trichiura* are not endemic in areas where land surface temperature exceeds 37°C (Brooker *et al.,* 2002a, 2002b). On the other hand, *N. americanus* infection occurs in tropical climates, and in some parts of the subtropics, and cannot survive during the winter season (Yong *et al.,* 1999). In some regions where marked rainy seasons occur, hookworm transmission rate is higher compared to regions with dry seasons (Udonsi *et al.,* 1980).

ii. Demographic factors

A. Age

Several previous studies revealed the age-dependency prevalence of STH infections. Although heavy hookworm infections still occur among children in some tropical areas, the peak prevalence and intensities for hookworm occurs in individuals in middle age, or even over the age of 50 (Bethony *et al.,* 2002). In China, a variance components analysis revealed that age was the most important contributor to infection intensity (28-30%), with age alone being responsible for 27% of this variation, and the study showed that *Ascaris* and *Trichuris* infections decrease after the age of 20 (Hotez, 2002b).

Moreover, many previous studies showed higher prevalence and intensity of *Ascaris* and *Trichuris* infections among young children (age below 10 years) when compared to their older counterparts (Anuar *et al.,* 2014; Al-Mekhlafi *et al.,* 2007; Naish *et al.,* 2004; Raso *et al.,* 2006). On the other hand, the prevalence of hookworm infections has been reported to increase significantly with age (Nasr *et al.,* 2013a; Bundy *et al,* 1988a). The nutritional and health status of the elderly in developing countries are often poor which makes them vulnerable to the morbidity associated with heavy hookworm infection (Tucker *et al.,* 2001). The age factor could be attributed to the different modes of transmission of these helminths.

B. Gender

The role of gender in STH infections is still unclear unless it is associated with other factors such as occupation and activities. Several surveys from Zimbabwe, Zanzibar, Tanzania and Papua New Guinea showed that males had higher prevalence of hookworm infections than females (Albonico *et al.,* 1997; Bradley *et al.,* 1992). In contrast, the prevalence of *Ascaris* infection has been found to be higher among females compared to males (Crompton, 1989b). All these associations are attributed to differences in the activities of the males and females in certain communities, while no study revealed any physiological variation.

iii. Socioeconomic factors

A. Poverty

Poverty is the root of almost all neglected tropical diseases including STH infections which are highly prevalent in poor and underprivileged communities. This may be attributed to the inadequate facilities that are essential in STH prevention and control. These include poor sanitation, unavailability of clean and treated drinking water and poor health care facilities (Anantaphruti *et al.,* 2004; Tomono *et al.,* 2003). Many previous studies in Malaysia and other countries showed that low household monthly income was a significant predictor of STH infections (Nasr *et al.,* 2013a; Ngui *et al.,* 2011; Naish *et al.,* 2004). Hence, STH infections are considered as the "cancers of the developing nations", according to Egger *et al.,* 1990). Moreover, these infections have negative impacts on the work capacity and future productivity of the infected individuals which may be reflected on the economy of the affected community which is trapped in a cycle of poverty, underdevelopment and disease (Bleakley, 2007).

B. Sanitation

Sanitation is considered a key factor for the transmission of intestinal parasitic infections. People in the rural areas and poor socioeconomic communities live with absence or inadequate sanitation including the absence of toilets and lack of provision of clean and treated water supply. Such situations cause STH infections to be easily transmitted vertically and horizontally as well (Campbell *et al.,* 2014). The absence of proper sanitation has been proven to be a significant risk factor of STH infections in different countries including Malaysia, India and Sri Lanka (Ahmed *et al.,* 2011; Gunawardena *et al.,* 2011; Ngui *et al.,* 2011; Rai *et al.,* 2000).

Higher prevalence and intensity of STH infections have been reported in communities where open defecation is a common practice. Defecation around the houses and play grounds is common in rural communities and this practice is likely to enhance the exposure and transmission of infections due to the contaminated environment. Previous studies have observed a 29% and 77% reduction in the prevalence of *Ascaris* and schistosomiasis respectively after the implementation of proper water and/or sanitation facilities (Esrey *et al.*, 1991).

C. Education and Occupation

Many previous studies have shown a significant association between parents' educational level and the prevalence of STH infections among their children (Al-Mekhlafi *et al.,* 2007; Quihui *et al.,* 2006; Phiri *et al.,* 2000). It is believed that educated parents are more aware about the health of their children and have better knowledge about the prevention of such infections compared to non educated parents.

Certain occupations influence the prevalence and intensity of STH infections. Occupation probably has a greater influence on hookworm epidemiology. In Sri Lanka, India, and Bangladesh, high prevalence of infection of STH is among workers and their families in the tea plantations, while high prevalence in Latin America occur among banana growers (Sorensen *et al.,* 1994). Engagement in agricultural work remains a common factor for human hookworm infection. Heavy infections reported in China and Vietnam are due to the use of fecal materials as soil fertilizer (Hotez, 2002b; Humphries *et al.,* 1997). Several surveys in China in 1988-1992 found the highest prevalence of hookworm among vegetable growers and farmers (Hotez *et al.,* 1997).

D. Household clustering

Higher prevalence rates of STH infections have been reported among people who live in houses made of wood and bamboo when compared with their counterparts who live in concrete houses (Holland *et al.,* 1988). This could indicate the nature of the culture and the presence of soils in the community which favor the transmission of STH infections. It could also be related to the type of floor in these houses, whether tiles/concrete or bamboo or sand.

Children living in large families have significantly higher prevalence of *Ascaris* infections compared to those from small families (Al-Mekhlafi *et al.,* 2007; Prakash *et al.,* 1980). The horizontal spread or the focal transmission of infection among family members in the vicinity of the home may explain this finding (Nasr *et al.,* 2013a; Anuar *et al.,* 2012). Similarly, previous studies revealed that the presence of other family members infected with STH increases the odds of infections among the family (Anuar *et al.,* 2014; Anuar *et al.,* 2012).

iv. Behavioral factors

The association between STH infections and personal hygiene practices is well documented. Hygienic behavior has proven to be a significant contributor to a sustainable control of STH infections, schistosomiasis, diarrhoea, and other fecal-orally transmitted diseases (Schmidlin *et al.,* 2013). Unhygienic personal practices such as not washing hands before eating and after playing with soil, walking barefooted, not washing vegetables/fruits before consumption, drinking untreated water and not cutting nails periodically were identified as significant predictors of STH infections in Malaysia and other countries (Anuar, *et al.,* 2014; Nasr *et al.,* 2013a; Schmidlin *et al.,* 2013; Ngui *et al.,* 2011; Acka *et al.,* 2010).

Poor personal hygiene could be due to poverty such as walking barefooted because of financial limitation and inability to afford shoes for all family members or practicing open defecation due to the unavailability of toilets inside the houses. However, it could also be due to the lacking of knowledge about the importance of specific behavior in controlling different diseases. For example, the availability of toilets does not necessarily mean that they are being used and people may still commonly practice open defecation due to habit (Schmidlin *et al.,* 2013; Ziegelbauer *et al.,* 2012).

v. Immunogenetic risk factors

Predisposition to all three STH species may have either an immunologic, genetic or even a combined immunogenetic basis. Previous studies from Bengal and New Guinea have identified individuals who are predisposed to acquiring heavy hookworm infections despite multiple exposures to the parasite and even anthelminthic chemotherapy and this is the same with *Trichuris* and *Ascaris* infections (Quinnell *et al.,* 2001; Thein-Hlaing *et al.,* 1987; Schad and Anderson, 1985). An association was found between hookworm specific IgM responses and diminished prevalence and intensity (Xue *et al.,* 2000). In some cases, immunoglobulin levels appear to be closely parallel to worm burdens (Haswell-Elkins *et al.,* 1989).

It was estimated that the heritability of hookworm load in Zimbabwe was 37%, indicating that 37% of the variation in quantitative hookworm egg counts was attributable to genetic factors (Williams-Blangero *et al.,* 1997). Similarly, 30-50% of *Ascaris* burden in Nepal and 28% of *Trichuris* in China were attributable to genetic factors (Williams-Blangero *et al.,* 2002). The results of a genome scan to *Ascaris* infection identified two genes, one on chromosome 1 and another on chromosome 13. It provided the first evidence that individual quantitative trait loci may influence the variation in STH burden (Williams-Blangero *et al.*, 2002).

2.1.6 Prevalence of STH infections

i. Global prevalence of STH infections

STH infections, among the most common NTDs, are still prevalent and of public health concern throughout the developing countries. About one third of the world's population is currently infected with one or more species of intestinal helminths (WHO, 2012). About 1220, 800 and 740 million people were infected with *A. lumbricoides*, *T. trichiura* and hookworm (*A. duodenale* and *N. americanus*), respectively (Pullan *et al.*, 2014). It was estimated that about 90% of children living in poor regions with inadequate hygiene and sanitation are infected with at least one STH species (WHO, 2010). The global prevalence and distribution of STH infections are shown in Figure 2.6.

After China, Southeast Asia and the Pacific Islands have the highest prevalence of STH infections followed by Sub-Saharan Africa and Latin America (Pullan *et al.*, 2014; WHO, 2002). A 4-year national survey showed that 531 million individuals (which represent (47%) of China's population) were infected with ascariasis, while the prevalence of trichuriasis was 19% with an estimated 212 million infections (Xu *et al.*, 1995). However, tremendous reduction in the prevalence of STH has been achieved throughout China (Kobayashi *et al.*, 2006; Wu, 2005). A previous study from India revealed that the prevalence of ascariasis, trichuriasis and hookworm infections were 91%, 72% and 54%, respectively (Naish *et al.*, 2004). Moreover, a study in the Kashmir state of India indicated that about 75% of school-aged children were infected with intestinal helminths (Wani *et al.*, 2010). Likewise, the prevalence of hookworm infections among aboriginal people in northern Australia was 93% (Thompson *et al.,* 2001).

In Africa, the prevalence was found to be high in the tropical areas of southern Cameroon, southwestern Nigeria and southeastern Africa with prevalence rates of more than 70%, (Ratard *et al.,* 1991; Pullan *et al.,* 2014). However, the prevalence of STH infections tends to be low in many countries in the Middle East and North Africa, except Iran and Yemen, and this could be due to the climatic conditions (Hotez *et al.,* 2012). For instance, a previous survey from three provinces in Morocco found a prevalence of less than 5% for trichuriasis and ascariasis while hookworm was not reported (El Idrissi *et al.,* 1999). On the other hand, Iran and Yemen are still highly endemic with STH infections. In Iran, the prevalence rates of ascariasis and trichuriasis were found to range from 41 – 76% and 0 – 19.6%, respectively (Fallah *et al.,* 2002). Similarly, high prevalence of ascariasis (61%) and trichuriasis (21%) were reported in Yemen (Raja'a and Mubarak, 2006).

The prevalence of STH infections in Brazil and Mexico have declined to less than 5% and this was attributed to improved family income, maternal schooling, improved sanitation and access to health care (Chammartin *et al.,* 2013a; Ferreira *et al.,* 2000; Carneiro *et al.,* 2002). However, the national prevalence of *Ascaris*, *Trichuris* and hookworm in Bolivia was estimated as 38.0%, 19.3%, and 11.4%, respectively (Chammartin *et al.,* 2013b).

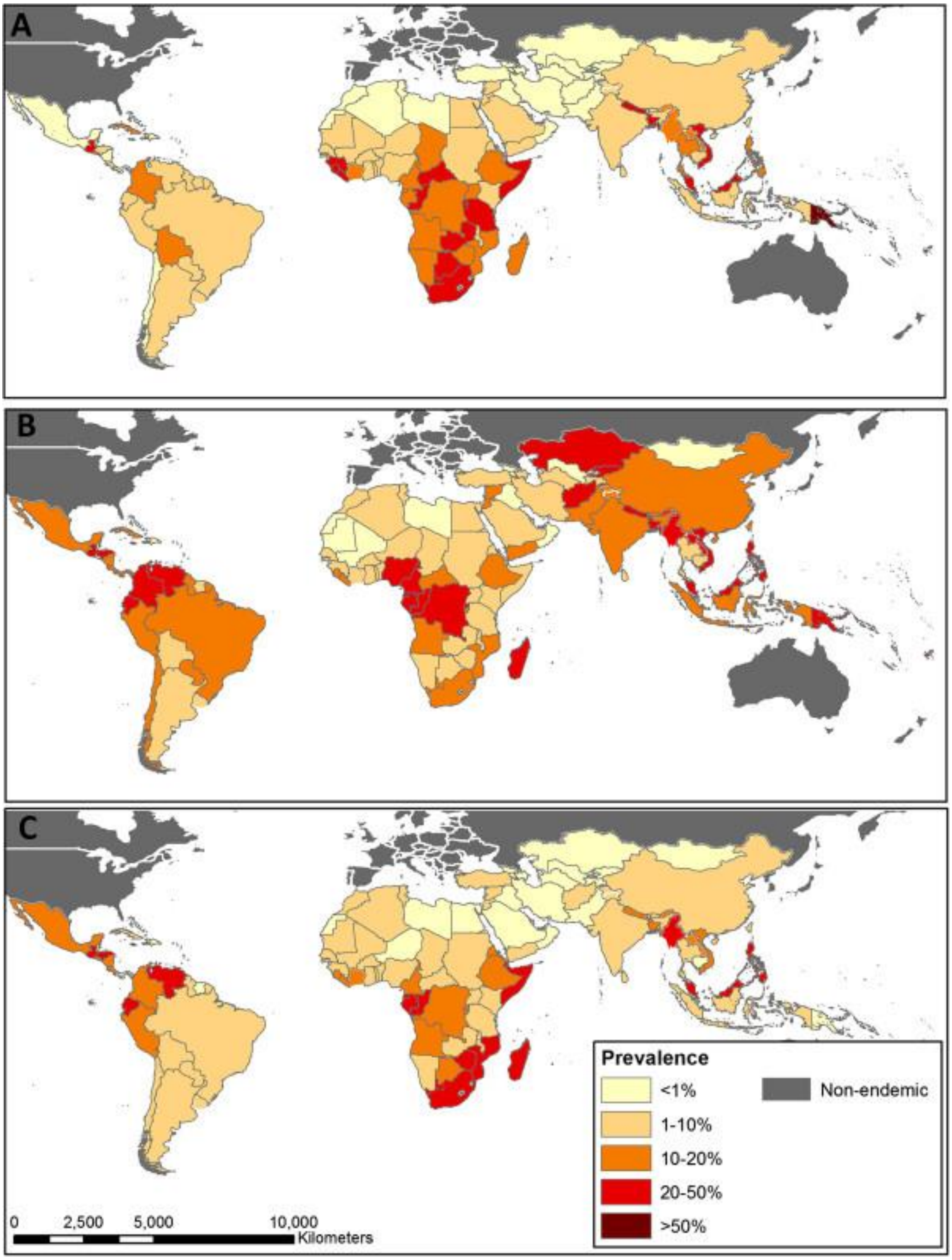

FIGURE 2.6: Global prevalence and distribution of STH infections (Source: with permission, Pullan *et al.,* 2014). **(A)** Hookworm, **(B)** *Ascaris lumbricoides* and **(C)** *Trichuris trichiura*; based on geostatistical models for sub-Saharan Africa and available empirical information for all other regions.

ii. Regional prevalence of STH infections

Southeast Asia has the second highest prevalence of STH infections, after China (WHO, 2002). The three STH species are widely distributed across Indonesia and earlier reports showed prevalence of 10.0–96.6 % for *Ascaris*, 1.0–98.0 % for *Trichuris* and 0.6–39.7 % for hookworm (Bang *et al.*, 1996). However, control programmes have successfully reduced prevalence levels to less than 30% in some areas of Indonesia (Margono, 2001). Moreover, a recent study to evaluate the impact of six rounds of mass drug (diethylcarbamazine and albendazole) administration on Brugian filariasis and STH infections in eastern Indonesia showed that the prevalence of trichuriasis, ascariasis and hookworm infections were reduced by 20.5%, 85.7% and 81.8%, respectively one year after the 5th round (Supali et al, 2013). However, the study indicated that the prevalence of these infections rebounded 34 months after cessation of drug administration.

In the Philippines, the prevalence among school-age children was found to be over 50% with prevalence rates of 21.0–51.7 % for *Ascaris*, 14.5–59.8 % for *Trichuris* and 0.5–7.5 % for hookworms (Belizario, 2009). Similarly, previous studies showed that Vietnam has high prevalence of STH infections in which about 44.4 % of the total population is infected with *Ascaris*, 28.6 % with hookworm and 23.1 % with *Trichuris* (Montresor *et al.*, 2007; Ehrhardt *et al.*, 2006). The results of a national survey in Vietnam showed that the prevalence of STH is highest in the northern part of Vietnam and lowest in the southern districts (Brooker *et al.*, 2003). With regard to Thailand, STH infections have been largely controlled in the urban areas where prevalence rates of 0.3% and 0.05 % were reported for hookworms and *Ascaris*, respectively (Warunee *et al.*, 2007). However, the prevalence was significantly higher in the rural areas of some provinces of the country where the prevalence could be as high as 60% (Waikagul *et al.*, 2002).

A story of success in controlling STH infections has been achieved by Cambodia in which the prevalence rates of *Ascaris*, *Trichuris* and hookworm were reduced by 92.3%, 79% and 70%, respectively (Moore *et al.,* 2012). This success could be explained by the high anthelmintics coverage rate; as of 2006, anthelmintic treatment reached 98% of school and 74% of preschool children (Montresor *et al.,* 2008). A similar successful control programme was conducted in Lao PDR; the mass administration of treatment was initiated in 2005 and reached 99% of the school-aged population by 2007 (Montresor *et al.,* 2008).

iii. Prevalence of STH infections in Malaysia

Ascaris lumbricoides, *T. trichiura*, and hookworm are the most common intestinal parasitic infections in Malaysia and the problem is worse in underprivileged rural communities. Several studies have demonstrated high prevalence rates of STH infections among underprivileged communities in rural areas in Malaysia, such as Orang Asli communities (Nasr *et al.,* 2013a; Ahmed *et al.,* 2011; Al-Mekhlafi *et al.,* 2006 and 2007; Norhayati *et al.,* 1997a), workers (Sinniah *et al.,* 1978; Kan, 1989; Li, 1990), rural Malay villagers (Zulkifli *et al.,* 2000; Rahmah *et al.,* 1997) and slum areas (Hanjeet *et al.,* 1991; Bundy *et al.,* 1988b).

Due to greater socioeconomic and infrastructural development, a tremendous reduction in the overall prevalence of STH infections in the urban areas has been achieved (Mahmood *et al.,* 2002; Jamaiah and Rohela, 2005). However, the trend in Orang Asli communities remains largely unchanged since the 1920s despite intensive efforts to improve the quality of life of these people. Several studies have demonstrated high prevalence rates of ascariasis, trichuriasis and hookworm infections in Orang Asli children, where the prevalence ranges between 30.2 – 69.0%, 15.8 – 100% and 6 – 51.0%, respectively (Anuar *et al.,* 2014; Ngui *et al.,* 2011; Al-Mekhlafi *et al.,* 2006;

Russell, 1928; Norhayati *et al.*, 1997a; Bundy *et al.*, 1988a; Kan, 1982; Sinniah *et al.*, 1978). Overall, these studies revealed *that T. trichiura* is the predominant species in Malaysia followed by *A. lumbricoides* and then hookworm. Interestingly, a previous study has detected *S. stercoralis* larvae in 7.1% of soil samples collected from the Lipis district (Azian *et al.*, 2008). Another study conducted in Kota Baharu, Kelantan reported *S. stercoralis* larvae in common local vegetables, herbs and fruits (Zeehaida *et al.*, 2011). These findings were supported by a recent study conducted on 54 Orang Asli individuals and 17 of them were tested seropositive for strongyloidiosis, and only three of them were confirmed by PCR as positive after *S. stercoralis* DNA amplification using fecal samples indicating acute infection (Ahmad *et al.*, 2013).

In the same vein, previous studies reported a rapid and high STH re-infection rate among Orang Asli children and showed that the prevalence and intensity of STH infections by six months after complete deworming was almost similar to pre-treatment levels (Al-Mekhlafi *et al.*, 2008b; Norhayati *et al.*, 1997b). It was suggested that mass treatment should be implemented together with other measures including providing proper sanitation and proper health education regarding good personal hygiene and good sanitary practices (Nasr *et al.*, 2013a; Ngui *et al.*, 2011). Moreover, recent molecular studies using multiplex real-time PCR assay for the detection of various species of STH showed that *N. americanus* and *A. ceylanicum* infections are found in rural Malaysia with the *N. americanus* infection being more common (Mahdy *et al.*, 2012; Ngui *et al.*, 2012).

A summary of findings from previous studies on the prevalence of STH in Malaysia is shown in Table 2.2.

TABLE 2.2: Previous studies on STH infections in Malaysia (1926-2014)

Year	Area/Setting	Sample size	Target group	Prevalence (%) *Ascaris*	*Trichuris*	Hookworm	Overall	References
1928	-	-	-	62.2	65.1	70.9	-	Russell, 1928
1929	-	-	-	-	-	61.0	61.0	Robertson, 1929
1929	Urban	-	-	86.5	-	5.8	-	Grey, 1929
1936	-	-	-	77.1	-	38.0	-	Wolfe, 1936
1938	-	-	-	70.0	14.0	26.0	-	Nevin, 1938
1953	-	-	-	4.6	3.1	90.8	-	Polunin, 1953
1970	Aboriginal	-	All ages	69.0	80.0	51.0	93.0	Bisseru, 1970
1972	Aboriginal	-	All ages	55.4	38.1	72.8	92.2	Dunn , 1972
1978	Rural	433	Adults	67.2	55.4	12.2	76.2	Khairul *et al.*, 1978
1978	Estate	150	Adults	52	56	28	82.7	Sinniah *et al.*, 1978
1979	Rural	834	Children	86.7	84.5	43.2	95	Lo *et al.*, 1979
1980	Estate	562	Adults	14.9	18.5	27.8	36.3	Zahedi *et al.*, 1980
1982	Urban	305	Children	17.4	14.8	2.9	39	Hamimah *et al.*, 1982
1982	Urban	7682	Children	21.9	44.5	4.6	50	George and OwYang, 1982
1982	Urban slum	25246	All ages	18.8	33	7.1	39.6	Kan 1982
1984	Rural	271	Children	41.7	74.2	28	86.3	Sinniah 1984

Continued

Year	Area/Setting	Sample size	Target group	Prevalence (%) *Ascaris*	*Trichuris*	Hookworm	Overall	References
1987	Rural	11874	Children	19.3	36.2	3.3	41.1	Kan and Poon, 1987
1988	Urban slum	1574	Children	49.6	62.8	5.3	66.7	Bundy *et al.*, 1988a
1989	Estate	819	All ages	33.9	36.4	15.6	51	Kan 1989
1990	Estate	1203	Children	71.6	82.8	14	83.2	Li 1990
1991	Urban Slum	9863	Children	33	49	6	58	Hanjeet *et al.*, 1991
1994	Urban slum	456	Children	7.1	47.1	2.9	79.5	Rajeswari *et al.*, 1994
1995	Aboriginal	59	All ages	18.6	35.6	13.6	61.5	Karim *et al.*, 1995
1997	Rural	363	Children	29.2	16.5	-	38.8	Hidayah *et al.*, 1997
1997	Aboriginal	205	Children	62.9	91.7	28.8	92	Norhayati *et al.*, 1997a
1997	Aboriginal	78	Children	59.5	41.7	6	79.8	Rahmah *et al.*, 1997
1997	Rural	249	Children	31.8	43.8	8.5	76.6	Raj *et al.*, 1997
2000	Rural	183	Children	62.8	38.9	12.6	69.4	Zulkifli *et al.*, 2000
2002	Urban	111	Children	4.6	2.1	-	51	Mahmood *et al.*, 2002
2002	Rural	355	All ages	7	37	5	41	Sagin *et al.*, 2002

Continued

Year	Area/Setting	Sample size	Target group	Prevalence (%) *Ascaris*	*Trichuris*	Hookworm	Overall	References
2005	Urban	246	All ages	0.8	4.5	0.4	6.9	Jamaiah and Rohela, 2005
2006	Aboriginal	281	Children	61.9	98.2	37	98.2	Al-Mekhlafi *et al.*, 2006
2007	Aboriginal	292	Children	67.8	95.5	13.4	100	Al-Mekhlafi *et al.*, 2007
2007	Aboriginal	74	All ages	25.7	31.1	8.1	59.5	Hakim *et al.*, 2007
2009	Aboriginal	716	All ages	38.5	66.8	12.8	73.2	Ngui *et al*, 2011
2010	Rural Malay	79	Children	20.0	30.4	0	37.0	Huat *et al.*, 2012
2010	Aboriginal	254	Children	47.6	84.6	3.9	93.7	Ahmed *et al.*, 2011
2012	Aboriginal	77	All ages	26.9	39.0	3.9	50.6	Sinniah *et al.*, 2012
2013	Aboriginal	484	Children	37.4	71.7	17.6	78.1	Nasr *et al.*, 2013a
2014	Aboriginal	500	All ages	23.8	57.0	7.4	70.7	Anuar *et al.*, 2014

2.1.7 Prevention and Control

The World Health Organization suggests three main and vital interventions to prevent and control STH infections. These interventions are mass periodic administration of anthelmintic drug, proper sanitation and effective health education (WHO, 2005).

i. Mass chemotherapy

The WHO has supported mass school-based deworming programs in areas with helminth infection prevalence over 50%, since mass treatment eliminates the need for costly individual parasitological screening (Warren *et al.,* 1993; WHO, 1987). The main aim of this strategy is to reduce the intensity of STH infections by reducing the proportion of heavily infected individuals in the human population (WHO, 2012). Therefore, regular treatment of school-age children and other at-risk groups (such as pre-school children and pregnant women) helps to avoid the morbidity of infection even if there is no improvement in safe water supply or sanitation (Savioli *et al.,* 2002). The WHO set a global target to provide regular deworming (single dose of albendazole, 400 mg, twice a year) to at least 75% of all school aged children at risk for STH infections by the year 2010 (WHO, 2001). However, about 70% of school children who are at risk of STH infections are still out of coverage by deworming treatment making a target of eradication of STH not possible (WHO, 2012).

A single dose of albendazole tablets twice a year is the recommended regimen for mass drug administration (WHO, 2005). However, main challenges to this strategy are that chemotherapy does not kill immature worms and cannot prevent the re-infection which can occur soon after treatment (Campbell *et al.,* 2014; Jia *et al.,* 2012). Moreover, there is an increasing fear of possible emergence of benzimidazole drugs resistance among human STH which occurs as a result of point mutations in nematode-β-tubulin gene; such resistance has spread rapidly in animal helminths (Diawara *et al.*, 2013; Vercruysse *et al.*, 2011).

ii. Sanitation

Sanitation is more important than independence (Mahatma Gandhi, 1923).

Sanitation has a major impact on the prevalence and intensity of STH infections (Haswell-Elkins *et al.*, 1989). According to WHO, the level of STH infections can be viewed as an index of a community's progress towards a desirable level of sanitation (WHO, 1981).

Humans are the definitive host for the three major STH, thus sanitation has a major role and permanent effect on the control of these parasites. Safe disposal of excreta and the use of proper latrines have been associated with a significant reduction in the rate of STH infections. The availability of safe water, sanitation, and hygiene (WASH) is essential for a long-term and sustained control and elimination of STH (Campbell *et al.*, 2014; Strunz *et al.*, 2014). WASH involves a safe water supply, proper and adequate sanitation infrastructure that ensures safe disposal of human excreta, and the promotion of good personal and household hygiene practices (such as hand washing before eating and/or after defecation, use of soap, wearing shoes when outside, washing vegetables/fruits before consumption, etc).

Interventions that include WASH have been shown to be highly effective in reducing the environmental contamination and curtail the transmission of STH (Esrey *et al.*, 1991). However, many challenges limit the implementation of WASH especially in rural areas of developing countries. These challenges include the high cost, lack of local government involvement, lack of advocacy and lack of perception among rural populations of the importance of improved sanitation (Cairncross and Valdmanis, 2006; Cairncross, 2003).

Previous studies showed that sanitation, with or without health and hygiene education, reduces the prevalence and intensity of STH infections, and this impact is improved when combined with deworming (Hawdon, 2014; Asaolu and Ofoezie, 2003). However, improving sanitation in highly endemic communities may not attain the desired impact without a parallel improvement in hygiene and health-related behaviors in the targeted population (Sow *et al.*, 2004). For instance, a previous study found that the introduction of latrines into a rural and underprivileged community only reduced the prevalence of hookworm infection by four percent (Huttly, 1990). Likewise, another study in Salvador, Brazil found that improved drainage and sewerage had only minimal impact on the prevalence and no impact at all on the intensity of hookworm infections (de Moraes *et al.*, 2004).

iii. Health education

Health education is an approach which attempts to change behaviors in a target population regarding a specific problem in a predefined period of time (Clift and Freimuth, 1995). The main purpose of health education is to enable people to gain control over the determinants of health behaviors that influence their health status and that of others (WHO, 1996). Therefore, intervention on health education was recommended as a first option for low socioeconomic communities in order to create the enabling environment for other strategies to thrive (Ekeh andAdeniyi, 1988). The goal of health education is to increase knowledge and understanding of health- related issues and to improve the health status of individuals (Muturi, 2005).

Health education must suit the socio-cultural and economic circumstances of the target population (Akogun, 1992). Hence, developing health education programmes requires that their design, administration, and outcomes be adapted to different socioeconomic and cultural settings (Parker *et al.*, 2004). Many previous studies have proven that health education improves people's knowledge on the cause, prevention and treatment of endemic diseases, encourages community participation in control programs, modifies people's beliefs and customs on disease-causing habits and promotes practice of sanitary behaviors and the use of intervention facilities (Kloos, 1995). Nowadays, health education has been listed first among national comprehensive programme for STH infections and schistosomiasis control because it can help people change their behavior, prevent or reduce infection.

It is recommended that behavior as related to values, social representations, beliefs, cannot be changed simply with health education alone (Cross, 2005; Gazzinelli *et al.*, 2005 كGlanz *et al.*, 2002). Hence, the interventions for controlling STH should involve treatment, improved sanitation, and health education (WHO, 2005). By the end of health education programme in Kanchanaburi province in Thailand, a previous study concluded that the overall prevalence of STH infection had decreased and health education raises the awareness. Successful education-based STH control interventions depend partly on an individual's willingness and ability to practice behaviors that reduce the risk of infection. School-based interventions, to control parasitic infections, should start early in primary school (Anantaphruti *et al.,* 2008).

2.2 HEALTH BEHAVIOR, HEALTH EDUCATION AND HEALTH PROMOTION

Health behavior, health education and health promotion activities are a fundamental requirement for all health professionals. Health behavior is the central concern of health education. It is included in every definition of health education and is the essential dependent variable in most studies on the effects of health education interventions. On the other hand, health education and health promotion are closely related but are not mutually dependent. It is found that many researchers are confused with both terms and consider health education as synonymous with health promotion and hence use them interchangeably (Sullivan, 2003).

Health education involves giving information and teaching individuals and communities how to achieve better health. Health promotion is a term of more recent origin than health education and basically it is the development of individual, group, institution and community to improve health knowledge, attitudes, skills and behavior to positively influence the health behavior of individuals and communities that influence their health (Whitehead, 2008). Individual's health is influenced by the family situation, the community, the environment, and the political situation. Hence, health promotion must include health education together with the related legal, socioeconomic, environmental, educational, and organizational interventions that are necessary to foster health (Tones *et al.*, 1990).

Nowadays, there are seven main settings for health education: schools, communities, worksites, health care settings, homes, the consumer marketplace, and the communications environment. Of these, schools, communities and homes are the most related to health education interventions against parasitic infections.

i. **Schools.** Health education or promotion interventions in schools include teachers training, classroom teaching and activities, and changes in school environments (Franks *et al.*, 2007). It is well documented that school-based interventions are well received and highly effective in behavior changes and the effects can be extended to the related communities.

ii. **Communities.** Community-based health education is always effective and enables it to reach large populations with media and interpersonal strategies. Community interventions in clubs, recreation centers, and neighborhoods have been successfully used by many studies to encourage healthy lifestyle, healthy nutrition, reduce risk of cardiovascular disease, and promote breast cancer detection (Emmons and Rollnick, 2001).

iii. **Homes.** Health education interventions are delivered to people, especially those at risk of specific problem, in their home settings. This can be done through home visits or through a variety of contemporary communication media such as internet, telephone, and mail (McBride and Rimer, 1999).

2.2.1 Health Behavior

Behavior is basically defined as "an observable act, such as stepping on a weighing scale". According to Gochman (1997), health behavior was defined as "those personal attributes such as beliefs, expectations, motives, values, perceptions, and other cognitive elements; personality characteristics, including affective and emotional states and traits; and overt behavior patterns, actions, and habits that relate to health maintenance, health restoration, and health improvement".

Moreover, Kasl and Cobb (1966) defined three categories of health behavior: Preventive health behavior (any activity undertaken by an individual who believes himself/herself to be healthy, for the purpose of preventing or detecting illness in an asymptomatic state), illness behavior (any activity undertaken by an individual who perceives himself to be ill, to define the state of health, and to discover a suitable remedy), and sick-role behavior (any activity undertaken by an individual who considers himself to be ill, for the purpose of getting well).

Many factors that influence or cause an action to occur, or not occur are known as behavioral determinants or mediating factors. These determinants can be either internal such as anxiety and belief or external such as peer pressure and supportive setting. It is important to identify these factors and understand their interactions and effects across different settings. Overall, five levels of influence for health-related behaviors have been identified in an ecological model (McLeroy *et al.*, 1988).

i. **Intrapersonal or individual factors.** These are the characteristics of the individual such as knowledge, attitudes, self-concept, and skills. They include gender, religious and ethnic identities, economic status, values, goals, expectations, age, genetics, etc.

ii. **Interpersonal factors.** These are the formal and informal social systems and groups providing identity and support including family, work group and friendship. They include roommates, advisors, customs, diversity, recreation, clubs, etc.

iii. **Institutional or organizational factors.** These are the social institutions or organizational characteristics, rules and regulations. They include class timetable, financial policies, competitiveness, environments, noise, air quality, safety, etc.

iv. **Community factors.** These are the relationships between organizations, institutions, and other networks within defined boundaries. They include location in the community, built environment, community leaders, commuting, parking, transportation, parks, etc.

v. **Policy factors.** These are the public, national, and global laws and policies. They include polices that allocate resources to establish and maintain environment to create a healthy campus, tobacco use in public, alcohol sales and consumption, green policies, foreign affairs, global warming, etc.

2.2.2 Health Education

There are many definitions for health education based on aims, settings and components. According to Griffiths (1972) "health education attempts to close the gap between what is known about optimum health practice and that which is actually practiced." In 1980, Green defined health education as "any combination of learning experiences designed to facilitate voluntary adaptations of behavior conducive to health" (Green *et al.,* 1980). Moreover, health education was also defined as "the process of assisting individuals, acting separately or collectively, to make informed decisions about matters affecting their personal health and that of others" (National Task Force on the Preparation and Practice of Health Educators, 1985).

It was also defined as "the activities that seek to inform the individual on the nature and causes of health/illness and that individual's personal level of risk associated with their lifestyle behavior (Whitehead, 2004). Thus, health education seeks to encourage individuals to accept a process of behavioral change through directly influencing their values, beliefs and attitude systems. Another definition by Tilford and Tones (2001) is that "a communication activity that enhances health prevention and eliminates ill health by attempting to change unhealthy lifestyle practices of individuals".

According to the WHO, health education is "any combination of learning experiences designed to help individuals and communities improve their health, by increasing their knowledge or influencing their attitudes" (WHO, 2014).

2.2.3 Health promotion

The term health promotion has been defined in numerous ways (Maben and Macleod-Clark, 1995). Tones and Tilford (2001) defined health promotion as "any intervention designed to foster health". It has also been defined as "increasing the level of well-being and self-actualization of a given individual or group" (Pender *et al.*, 2002). Saylor (2004) defined health promotion as "lifestyle coaching designed to promote optimal health, quality of life, and well-being". Green and Kreuter provided a slightly different definition that "any combination of health education and related organizational, economic, and environmental supports for behavior of individuals, groups, or communities conducive to health" (Green and Kreuter, 1991). Moreover, the WHO's definition of health promotion is "the process of enabling people to increase control over, and to improve, their health" (WHO, 2014).

Health promotion focuses on the socioeconomic and environmental determinants of health with a participatory involvement in public health policy formulation and political change to ensure that the environment is conducive to health (Whitehead, 2008; Mackintosh, 1996). Moreover, health promotion includes health education, identification and reduction of health risks for targeted individuals and populations, empowerment, advocacy, preventative health care, and health policy development (Tilford and Tones, 2001).

2.3 HEALTH EDUCATION THEORIES AND MODELS

In order to develop an effective health education intervention, health education should be designed with a full understanding of recipients' or target populations' social background, beliefs, attitudes, and past behaviors (Green, 1974). Similarly, an understanding of theories of behavior change and an ability to use them skilfully in research and practice is also crucial (Grol *et al.*, 2007). There are a number of important theories and models that support the practice of health education. These theories can be classified into two groups based on the setting (Downie *et al.,* 1990). The first group involves theories that explain health behavior and health behavior change at the individual level; for example health belief model, protection motivation theory, theory of reasoned action and transtheoretical (stages of change and processes of change) Model. The second group involves theories that explain the changes and actions for health at the community and organizational levels; for example community mobilisation (social planning, social action and community development) and diffusion of innovation.

2.3.1 Health Belief Model

The Health Belief Model (HBM) was developed in the early 1950s to explain the widespread failure of people to participate in programmes designed to prevent and detect diseases (Hochbaum, 1958). Then, it was extended to study people's responses to symptoms and their behaviors in response to a diagnosed disease (Becker, 1974). The model has been one of the most widely used conceptual models in health behavior research to explain health behavior by understanding people's beliefs about health focusing on the individual, and also as a guiding framework for health behavior interventions. It contains several primary concepts that predict why people will take action to prevent or to control illness conditions. HBM is based on the understanding that a person will take a health-related action if he feels that a negative health condition can be avoided and would avoid negative health condition and believes that they can successfully take a recommended health action (Glanz *et al.,* 2002; Glanz *et al.,* 2008).

The model suggests that the likelihood of an individual taking action for a given health problem is based on the interaction between four types of beliefs. These include susceptibility, severity, benefits and barriers to a behavior and most recently, self-efficacy (Nutbeam and Harris, 2004).

i. **Perceived susceptibility.** Perceived susceptibility refers to one's beliefs about the likelihood of getting a disease or condition. For instance, an individual must believe there is a possibility of acquiring helminth infections before he/she will be interested in obtaining anthelmintic drugs.

ii. **Perceived severity.** One's opinion about how serious a condition and its consequences are or of leaving it untreated and this include both medical and clinical consequences (e.g. pain, disability, death) as well as possible social consequences (such as effects of the conditions on work capacity and family life). For example, one's believe that the consequences of acquiring severe hookworm infection are significant enough to try to prevent.

iii. **Perceived benefits.** One's belief in the efficacy of the recommended action to reduce risk or seriousness of a condition. For example, one's believe that the recommended action of wearing shoes would protect him/her from acquiring hookworm infection.

iv. **Perceived barriers.** The potential negative aspects of a particular health action may act as obstacles to undertaking recommended behaviors or actions (it could help me, but it may be expensive, have negative side effects, inconvenient, or time-consuming, etc). For example, people have realized the importance of using toilets in controlling STH infections, but the cost is high.

v. **Self-efficacy.** It is the confidence in one's ability to take action or behavior required to produce the outcomes (Glanz *et al.,* 2002). For example, individual confident in boiling drinking water.

The component and constructs of HBM are illustrated with some factors as examples in Figure 2.7.

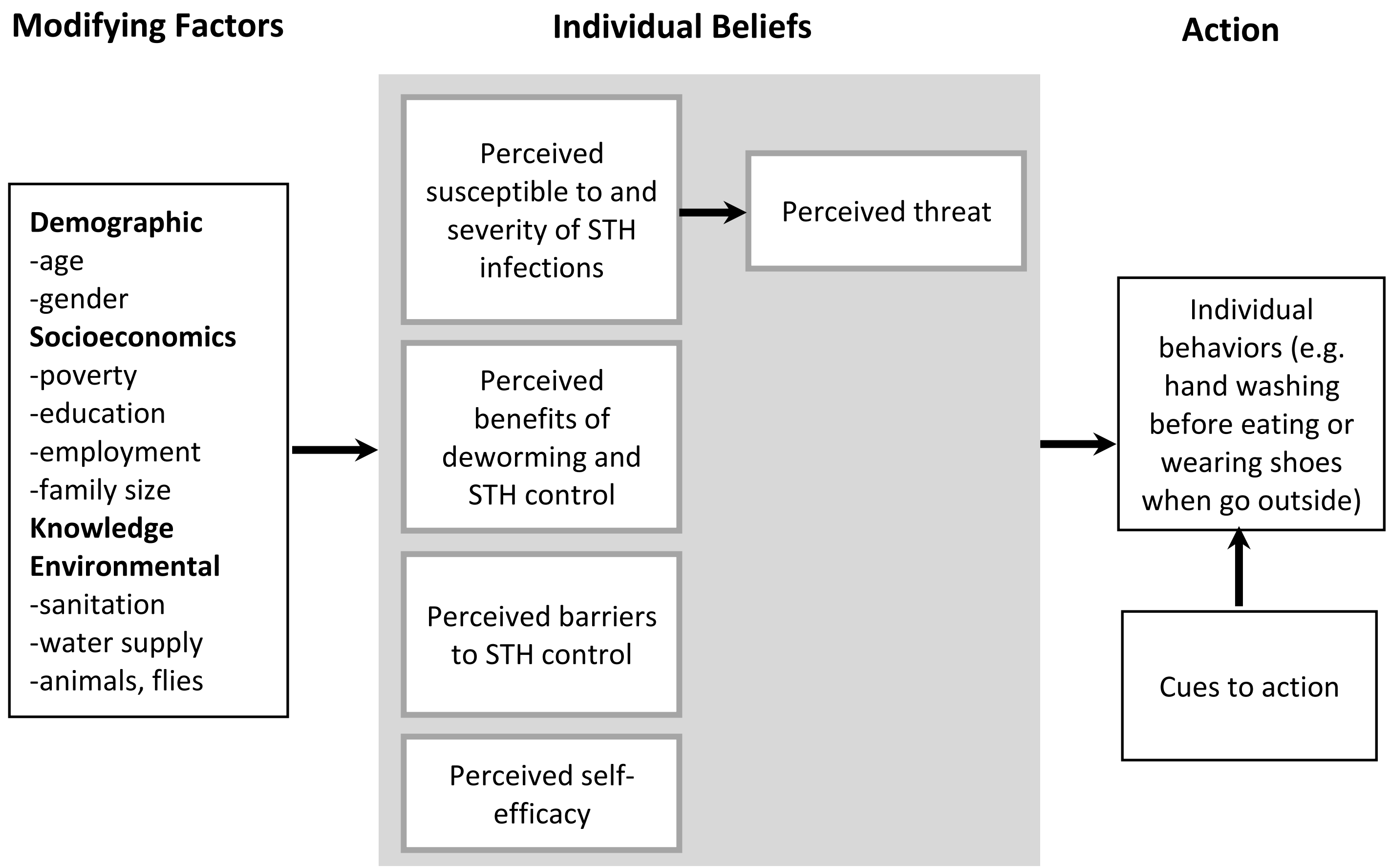

FIGURE 2.7: The component and constructs of Health Belief Model applied on STH (Source: modified from Nutbeam and Harris, 2004)

2.3.2 Theory of Reasoned Action

In this theory, the most important determinant of behavior is behavioral intention, and the direct determinants of people's behavioral intention are their attitude toward accepting the recommended behavior and their subjective norm associated with that behavior (Ajzen and Albarracin, 2007).The theory postulates that individuals who have strong beliefs that positively valued outcomes will result from doing the behavior that have a positive attitude toward the behavior. Similarly, an individual's subjective norm is determined by his/her normative beliefs, that is, whether important referent individuals approve or disapprove of undertaking the behavior. The determinants of reasoned action theory are summarized in Figure 2.8.

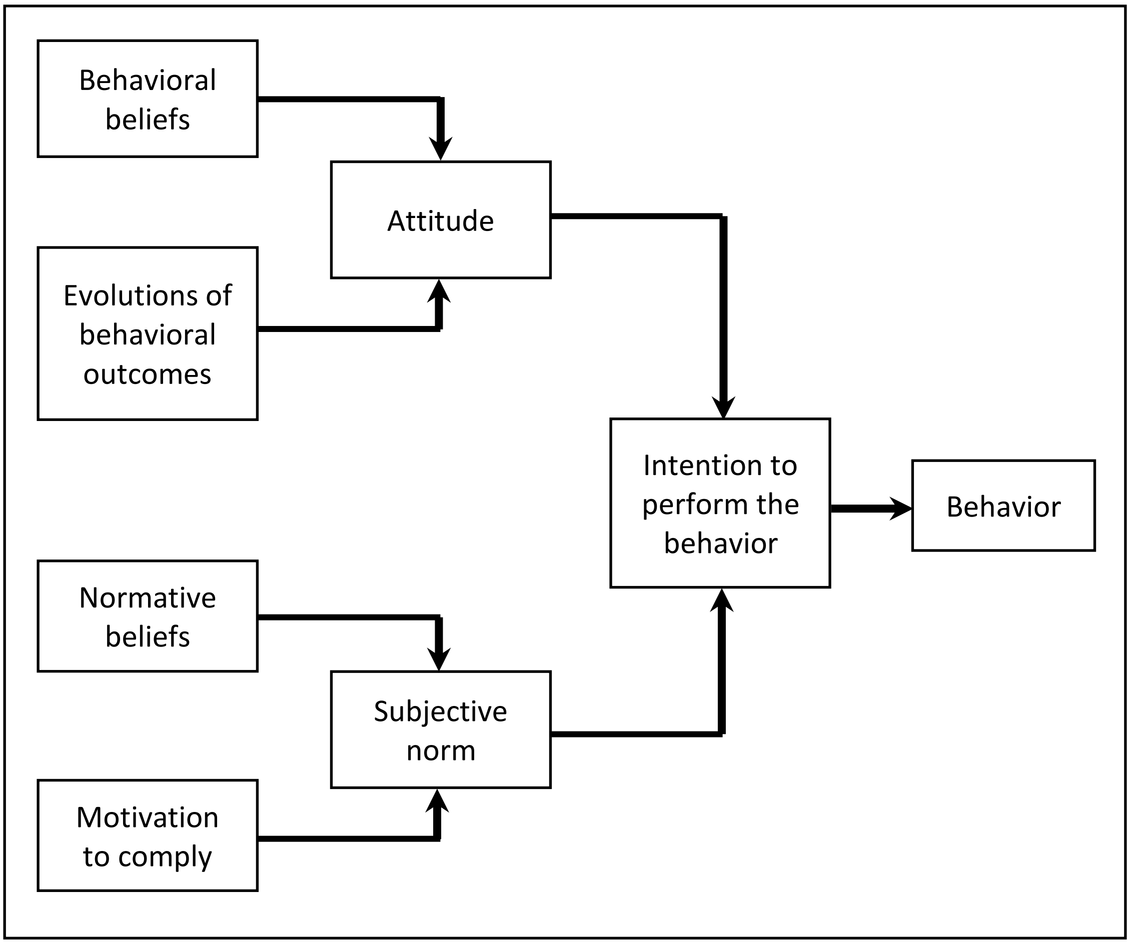

FIGURE 2.8. The determinants of reasoned action theory. (Source: Ajzen and Albarracin, 2007).

2.3.3 Precaution Adoption Process Model

The Precaution Adoption Process Model (PAPM) also postulates that individuals go through few stages (due to qualitative differences among people) before accepting and modifying their behaviors and then the model describes the changes by a single prediction equation (Weinstein and Sandman, 1992).

The PAPM clearly presented a stage in which the targeted people may be unaware of a risk or precaution, and it includes a stage in which people have decided not to act. The theory also explains how quickly people may go from a stage of unawareness to awareness and action. The stages of PAPM and a simple example of using toilets and stop open defecation are illustrated in Figure 2.9.

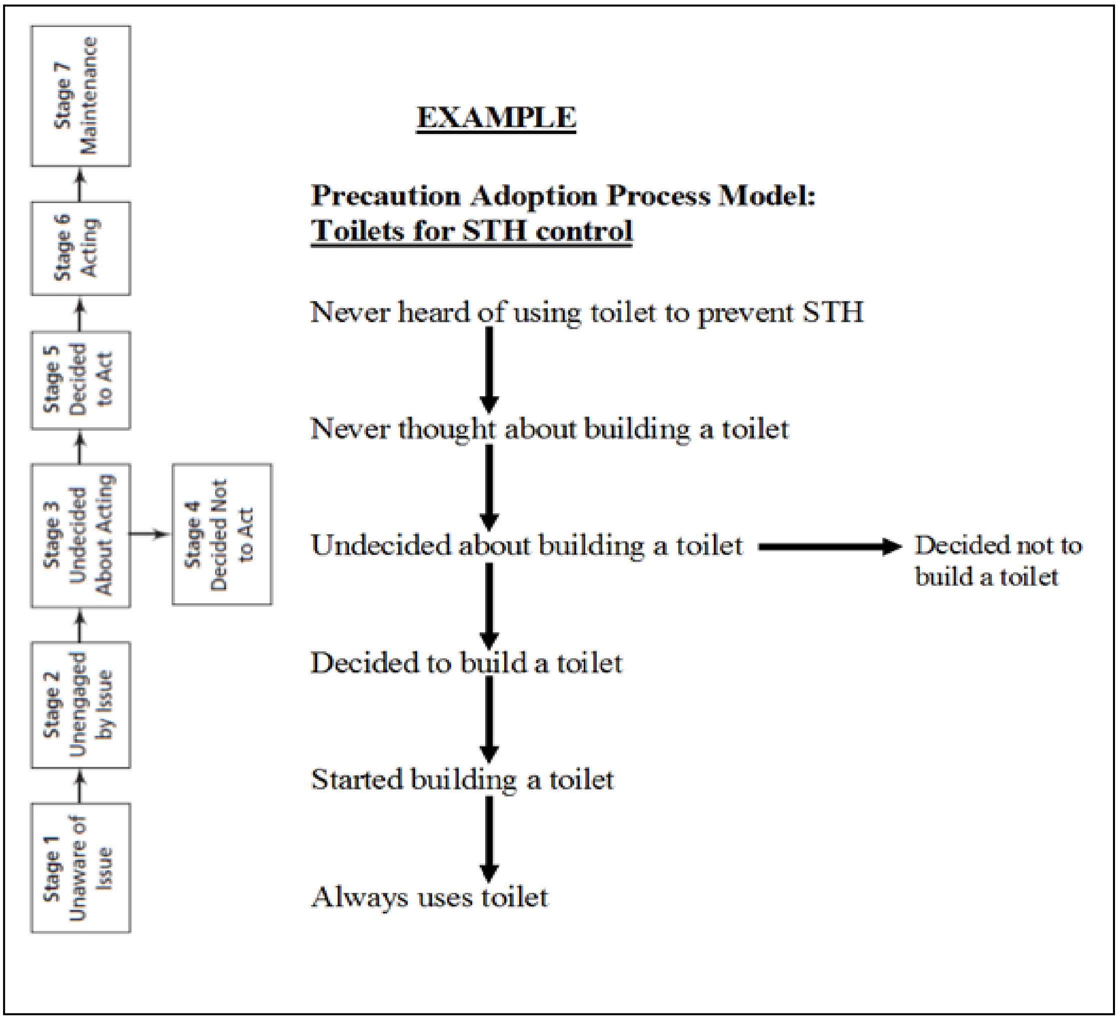

FIGURE 2.9: The stages of PAPM and an example of using toilets to prevent STH infections.

2.3.4 The PRECEDE-PROCEED Model

The PRECEDE-PROCEED Model (PPM) was developed and introduced in 1974 by Dr. Lawrence W. Green to help health programme planners, policy makers, and other evaluators to analyze situations and design health programs efficiently (Green, 1974). In this model, PRECEDE stands for predisposing, reinforcing, and enabling constructs in educational/ environmental diagnosis and evaluation while PROCEED stands for policy, regulatory, and organizational constructs in educational and environmental development (Karen *et al.*, 2008). The model was considered as a road map to present all the possible avenues, whereas the theory suggests certain and specific avenues to follow.

Unlike the theories described previously, the main purpose of the PPM is not to explain or predict the relationship among determinants thought to be associated with a specific outcome. But, its main rationale is to provide a comprehensive structure for applying theories and concepts systematically for planning and assessing health behavior change programmes. Hence, PPM is a community-involvement model that provides a comprehensive structure for assessing health and quality of life needs, and for designing, implementing, and evaluating health promotion and other public health programmes to meet those needs (Figure 2.10).

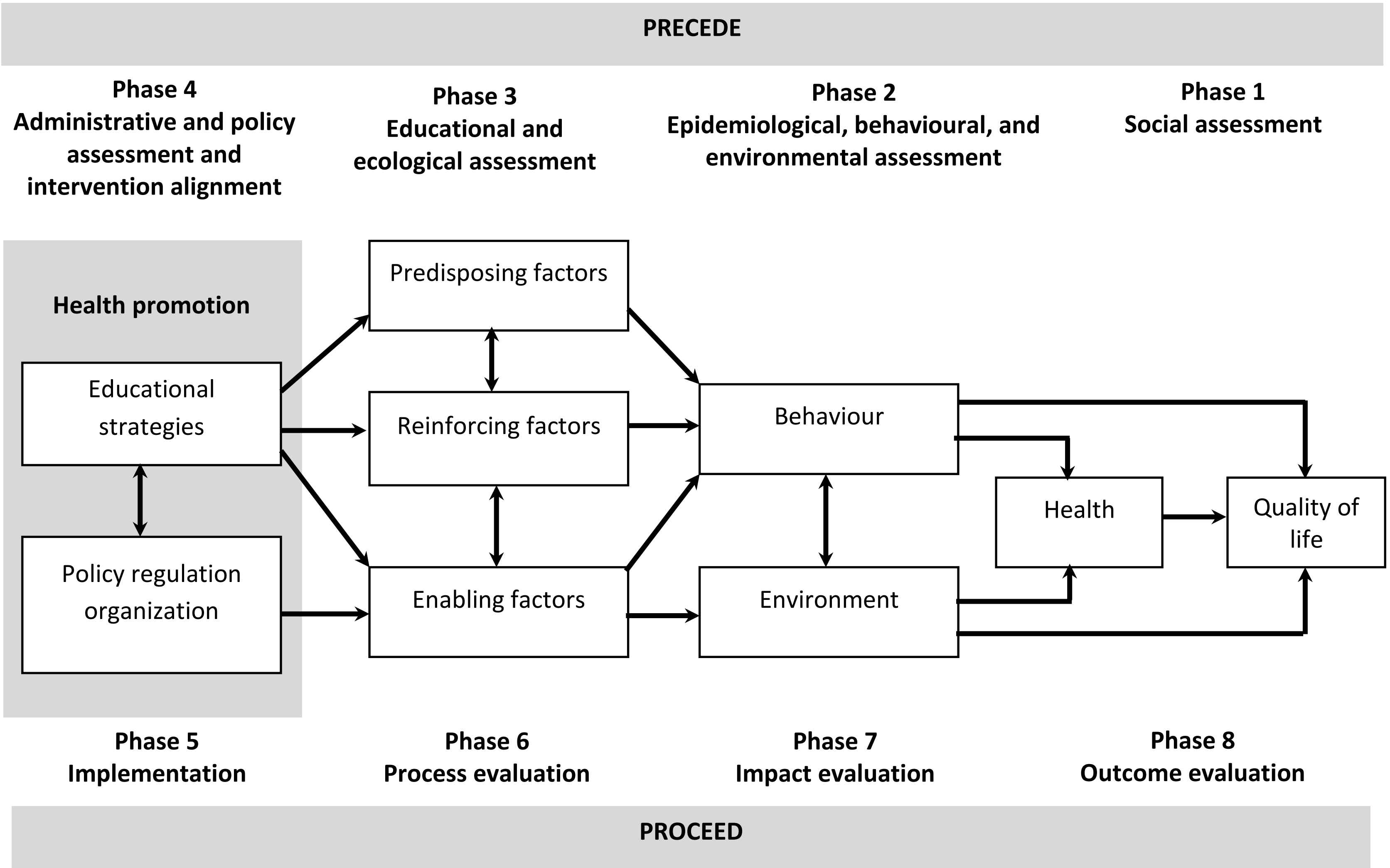

FIGURE 2.10: PRECEDE-PROCEED Planning Model. (Source: modified from Crosby and Noar, 2011)

2.4 BEHAVIOR CHANGE: A SIMPLE OR DIFFICULT TASK?

When a behavior is easy and resistance is low, interventions and health messages provided to help the target population progress from stage to stage can be simple and brief. In contrast, when change is difficult and level of resistance is high, there is a greater need to have separate messages for each stage. In some situations, the change is easy and resistance is low, but the impact of interventions was minimal due to the ignorance for the effects of other determinants or obstacles. For example, wearing shoes when going outside is clearly easy to carry out and no resistance to be declared, but may be poor people may not be able to afford shoes for their children and perform this easy behavior. Hence, health professionals should not assume that change is easy without considering carefully the possible obstacles that may exist.

Moreover, individuals are influenced by their social milieu, e.g. family, friends, co-workers, and so forth. This can be considered as a critical factor to achieve behavior change and it should be considered when trying to find the answers for why are people's behaviors difficult to change? Why do interventions often fail short of their behavior altering goals? Individuals in developing countries, especially those in poor socioeconomic communities enjoy less freedom to make strictly personal decisions when considering whether to accept and perform a new behavior, than their counterparts in the developed countries. Hence, these people and also children will consider more deeply the interests and opinions of their parents, peers and community along with their own preferences (McKee *et al.,* 2008). Therefore, programmes should aim to reach beyond the targeted individuals to include the people who influence the individuals and their behavior and decision.

The best interventions are those designed to consider community mobilization and involving people in evolving behavior. An integrated approach towards involving people in evolving behavior is summarized in Figure 2.11. Besides the surrounding family and community, the approach focus on the two outer rings of the diagram; i.e. ‘enabling environment’ and ‘ability to act’, and the two inner rings; i.e. ‘information’ and ‘motivation’.

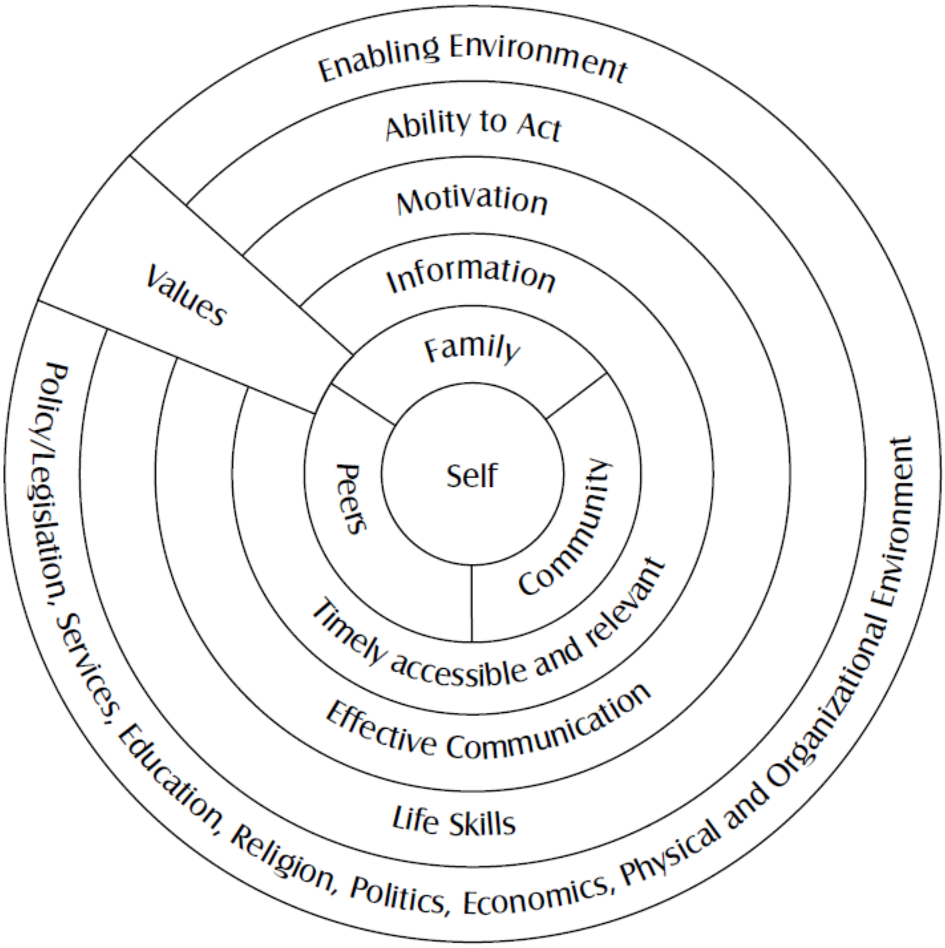

FIGURE 2.11: Involving people in evolving behavior model. (Source: McKee *et al.*, 2008)

2.5 IMPORTANCE OF HEALTH EDUCATION FOR HELMINTH INFECTIONS PREVENTION

It is well documented that school-aged children have both the highest prevalence rate and the highest intensity of STH infections. STH infections are associated with growth retardation, anemia and impairment of school performance which can be reversed by treatment to normality (WHO, 2011). In the long term, STH infections cannot be controlled by mass chemotherapy alone. An integrated approach, involving behavioral, educational, and environmental factors is greatly required to ensure a sustainable control (Pullan *et al.*, 2014). Hence, helminth infections are considered as the entry point to foster health promotion in schools as well as healthy lifestyle and healthy nutrition. Besides the cost-effectiveness of using available facilities in schools, the school-based health education component aimed at recognizing the conditions for an effective health education leading to better health. The main concepts and strategies within the health education activities are participation and action. School children participation is considered to be the most important requirement for affecting children's daily actions and behaviors (Simvoska, 2004). The action-oriented and participatory approaches in health education support the development of children's abilities to create change.

In 1995, the WHO launched the 'Global School Health Initiative' which provides a vision for the development of comprehensive school-based efforts to improve health, and health-promoting schools (WHO, 1997). According to this initiative, health-promoting school (HPS) is a school that strives to constantly strengthen its capacity as a healthy setting for living, learning and working. Various health problems have been prioritized to be considered as an entry point for these schools; these included malnutrition, helminth infections, smoking, HIV/AIDS infection, dental problems, etc. In 2000, Lao PDR launched the health promotion schools (HPS) in 30 schools, recognizing that poor nutrition contributes to half of all child mortality and that poor sanitation and personal hygiene contribute to the high incidence of helminths among children. In China, an HPS pilot project was established in 1996 and successfully reduced helminth infections in rural schools (Xu *et al.*, 2000).

In Philippines, an integrated package called “Urbani School Health Kit” was developed at the WHO Western Pacific Regional Office and was named in honor of the late Dr. Carlo Urbani, an expert in the control of parasitic diseases including helminthiases and malaria. The kit contains materials that can support health education and health promotion activities in schools and help teachers to educate children about prevention of health problems and to implement appropriate interventions. It also empowers teachers, students, parents, health providers, and community leaders in making the school a healthy place. Hence, the kit demonstrates the principles of the HPS and fosters health and learning.

The kit emphasizes the role of teachers in promoting health among children and motivates teachers to be role models for health promotion about the most important health problems in their community. It also encourages the teachers to motivate children to make healthy choices, to understand the importance of healthy living, and to take action to improve their own health. Teachers are also challenged to identify how health education can be linked to the topics taken in the main school curriculum.

The kit cases show important health issues, health activities, and resource materials for a healthy school programme. It focuses on seven key issues; improving personal hygiene, oral health, diet and nutrition, keeping the environment clean and healthy, preventing worm infections, saying no to tobacco and preventing malaria and dengue. The materials are contained in a medium size cabinet with wheels that are durable and easily transported within schools. Hence, this kit is suitable to be used within schools only. Moreover, the community involvement is too minimal. The sides of the cabinet can be used to hang posters for each key issue. Other materials are provided for indoor and outdoor activities, such as models of human mouth with teeth, toothbrushes, toothpaste mimic, game cards, a soft ball, and soft dice. A guide booklet on games explains the basic rules on how to play several games (for teaching and evaluation), using the materials provided.

A previous study was conducted in six primary and secondary schools with 6188 students in China for one year (Long-Shan *et al.,* 2000).The study evaluated some interventions which include: examination and treatment of helminth infections; health education; improvement of school physical environment; establishment of relevant school policies and regulations; and strengthening relationship between school and community in comparison with deworming only in two control schools. In this study, health education classes were added to the teaching agenda and given once every two weeks. Teaching materials for the health education classes consisted of a text book on health education (2 versions*;* for primary schools and secondary schools*)*, monthly wall newsletters and broadcasting messages throughout the school campus, colored pictures on the “parasitic diseases and health” and also on the “control of common parasitic diseases in humans” were distributed to each student. Moreover, the students were encouraged to share these pictures and other health-related messages with their parents and siblings. Besides, a video on the control of parasitic diseases was also shown in class, and slides demonstration sessions of adult worms and eggs under a microscope were organized.

After one year, the findings showed significant reductions by 80% and 75–100% in the worm infection rate among children and the egg contamination of the school environment in the intervention schools respectively compared to the non significant changes in the control schools. Moreover, remarkable improvements in students' knowledge, behavior and skills with regard to health protection, improvements in school physical facilities and the school/community relationship was strengthened among experimental schools. These findings revealed that the concept of the health-promoting school has been well accepted by the students, teachers, parents and local government officers as well.

A recent study in Bangladesh reported good improvements in the knowledge about intestinal helminth in the areas that received health education (Minamoto *et al.,* 2012). Similarly, health education about helminths resulted in significant improvements in nail trimming, hand washing with soap before and after preparation and serving food, and after defecation (Mascie-Taylor *et al.,* 2003). Systematic health education programmes, construction of latrines, disinfection of vegetables, and the use of chemical fertilizers were implemented in Japan and resulted in the elimination of ascariasis (Hong *et al.,* 2006). A similar success was reported in Korea by the administration of anthelmintic drugs twice annually with the health education and construction of sanitary latrines (Yap *et al.,* 2012).

In Africa, it was reported that through health education intervention project, teachers and public health staff learned about the impact and control of parasitic diseases gained by changing human attitudes and health habits. A previous study was carried out among 50 primary schools for a period of one school year to examine the feasibility and effectiveness of introducing active teaching methods related to health education on schistosomiasis and helminth infections in Tanzania (Lansdown *et al.,* 2002). The means for health education involved a workshop for teachers, songs, poetic dramas, short plays, visits and discussions. The study revealed that changes in both knowledge and health seeking behavior related to these infections have been improved. Moreover, the responses from parents were investigated and found to be positive. For instance, mothers said that they had learned a lot from their children, others said that they had been pressurized by their children, e.g. to wash hands/ vegetables before cooking, to build a new toilet or to boil drinking water. Moreover, many of them explained that they would like to do more but lack money, e.g. wearing shoes when doing outdoor activities.

Similarly, the effect of three health education schemes on the knowledge and attitude towards certain parasitic diseases including malaria and helminth infections was evaluated among 1383 respondents in Kanuri, Nigeria (Akogun, 1992). The schemes were 1- pictures and card games (used as control), 2- drama songs, storytelling and discussions, and 3- a combination of both knowledge and attitude was tested. The findings showed that the combination scheme was the most effective and women were more influenced than men by health education schemes which involve drama songs and stories compared to card games and pictures. Moreover, a previous study showed the effect of health education intervention programme conducted in Nigeria in decreasing the prevalence and intensity of *Ascaris* infection by more than 26% and 35%, respectively (Asaolu and Ofoezie, 2003).

A national project was carried out in Seychelles for two years to increase public awareness and provide information about intestinal parasitic infections (IPI) control using printed materials (newspapers, posters, leaflets) and electronic media (radio, television, audiovisual aids) (Albonico *et al.*, 1996). These include a video film produced by the control programme and the WHO, and a leaflet on the prevention and control of IPI. The project achieved 44% reduction in the prevalence of IPI. The intensity of *Trichuris* infection, the predominant parasite, was reduced by 50% (from 780 to 370 eggs per g of feces). The Republic of Seychelles is a small country (459 km^2) with a population of 88,303, the smallest population of any African state and this was an advantage to implement such programme at the national level.

Similarly, another study showed significant reduction in both the frequency and intensity of *Ascaris* and *Trichuris* infections among elementary school children in Central Java in which the children were dewormed and provided with 6-7 months of behavioral remediation instruction which involved community meetings, songs and posters (Albright and Basaric-Keys, 2006).

A cluster randomized controlled trial was conducted among 18 primary schools in the Peruvian Amazon to evaluate the effects a school-based health hygiene education on STH re-infection after four months of treatment (Gyorkos *et al.,* 2013). The health education interventions of this study consisted of a short classroom activity to describe STH transmission and prevention using a 32-page booklet on STH, and a half-day workshop for teachers on how to develop innovative ways to help children improve their personal hygiene practices and how to prevent STH infections. The study revealed significant reduction in *Ascaris* infections and significantly positive improvements in the knowledge about STH and in water treatment behavior among children from intervention schools compared to children from control schools.

A recent study aimed at developing and evaluating a cartoon video on STH infections among Chinese children revealed that the knowledge about STH infections was significantly improved and the incidence of infections was 50% lower in the intervention group than in the control group (Bieri *et al.,* 2013). Children in the intervention group received a health education package which included a teacher-training workshop, cartoon video show in the classrooms followed by a 10-15 minutes discussion, handout pamphlet summarizing the key messages delivered in the cartoon video, drawing and essay competitions while the control group received only poster.

On the other hand, a previous study in Jakarta, Indonesia found no significant difference in the prevalence of *Ascaris* infection between children who received a health education intervention for 5 months and their counterparts in control group (Hadidjaja *et al.,* 1998). Similarly, Aung *et al.,* (1988) found no significant impact for hand washing intervention among children in Rangoon, Burma.

2.6 HEALTH EDUCATION PROGRAMMES IN MALAYSIA

Health Education Division is one of the five divisions under the Public Health Department in the Ministry of Health, Malaysia. It was started as the Health Education Unit in 1968. The general objective of this division is “to enhance health knowledge and inculcate positive attitudes towards health and promote the adoption of healthful living among the individual, family and community as a whole” (MOH, 2008). The division has organized many campaigns and awareness activities, such as world AIDS day, national anti-mosquito and cleanliness campaign, family health, dental health, mental health day, breast feeding week, no tobacco week, hypertension awareness week, organ donation, world heart day and world diabetes day. It was found that there has been no health education programme on helminth infections. This could be explained by the fact that these infections have been largely eliminated in the urban areas and they are the main health problems among Orang Asli and few other rural groups.

Moreover, an interesting and successful programme called “Program Doktor Muda translated as “Young Doctor’s Programme” has been implemented in 1860 schools throughout Malaysia (JDC, 2014; Yusof and Jaafar, 2013). Young doctors are a group of students that have been trained in relevant aspects of health so that they can improve their own health and also play an important role as health agents to promote good health knowledge and practices to their peers and family members. These young doctors act as role-models and guide their friends and families to give appropriate attention towards the adoption of healthy lifestyle.