



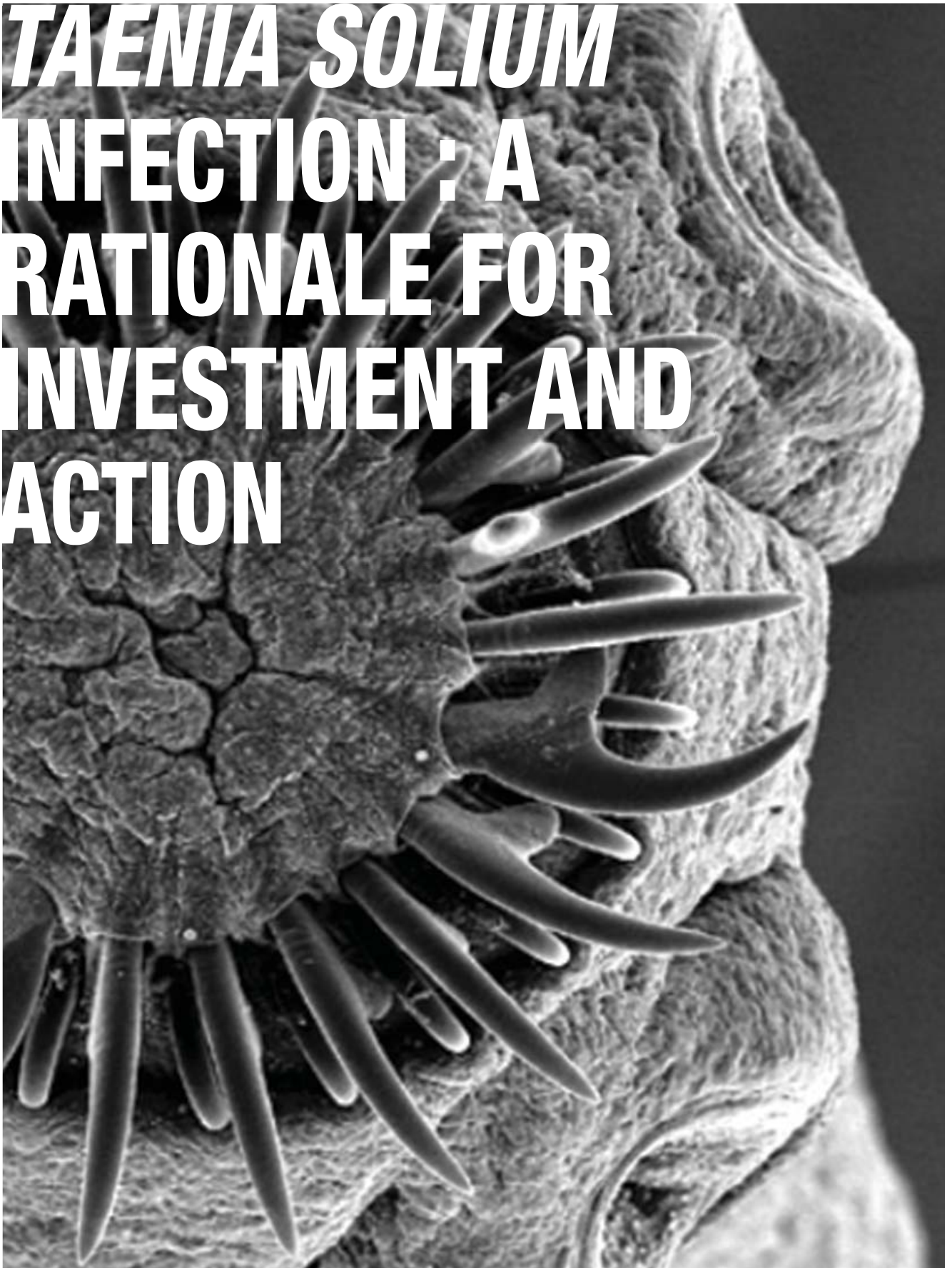
PREVENTABLE EPILEPSY: *TAENIA SOLIUM*
INFECTION BURDENS ECONOMIES,
SOCIETIES AND INDIVIDUALS

A RATIONALE FOR INVESTMENT AND
ACTION

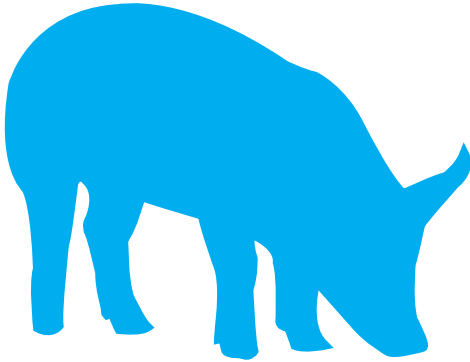


**World Health
Organization**

TAENIA SOLIUM
INFECTION : A
RATIONALE FOR
INVESTMENT AND
ACTION



**NEUROCYSTICERCOSIS
IS THE LEADING CAUSE
OF PREVENTABLE
EPILEPSY
WORLDWIDE.**



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Preventable epilepsy: taenia solium infection burdens economies, societies and individuals: a rationale for investment and action.

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Executive summary: Why investment is needed

Rationale 1: *T. solium* infection is a serious yet under-recognized public health concern

NEUROCYSTICERCOSIS BURDENS ECONOMIES, SOCIETIES AND INDIVIDUALS BECAUSE OF THE IMPACT OF EPILEPSY ON WAGES, HEALTH COSTS AND SOCIAL STIGMATIZATION OF SUFFERERS.

Burden of *T. solium*: Neurocysticercosis is a disease induced by *T. solium* larvae penetrating human tissues, especially the nervous system. Neurocysticercosis burdens economies, societies and individuals because of the impact of epilepsy on wages, health costs

and social stigmatization of sufferers. Health systems are also burdened as treatments must be tailored to individual needs.

Lack of awareness and understanding: Lack of awareness and understanding about the conditions leading to infection with the pig tapeworm *T. solium* has contributed to the neglect of this disease, which occurs mainly among the poorest populations of the world.

Diagnostic gap: Lack of neuroimaging facilities and point of care tests is an important reason for the gap in diagnosis and treatment of neurocysticercosis and may contribute to the disease burden.

Importing the disease: *T. solium* also threatens developed nations when taeniasis cases are imported.

Rationale 2: *T. solium* control is possible with investment in existing tools

Health Education: Health education campaigns can target the general population, health workers, pig farmers and meat workers and focus on the biology of the disease, improvements in meat preparation and personal hygiene and the need for adequate sanitation/ improved pig husbandry.

Human preventive chemotherapy: Preventive chemotherapy involves the distribution of drugs at regular intervals to human populations at risk in order to destroy parasitic worms.

Chemoprophylaxis and vaccination in pigs: Chemoprophylaxis and vaccination in pigs has been widely used as a control strategy with demonstrated high efficacy in protecting pigs from cysticercosis.

Improved Sanitation: Ensuring that sanitation facilities are available and used has public health advantages beyond *T. solium* control.

Pig farming practices: Encouraging farmers to adopt better farming practices, specifically by confining

pigs to prevent their access to human faecal material, is consistently included in recommendations for *T. solium*.

Meat inspection and processing: The aim of meat inspection is to break the life-cycle of *T. solium*, considered to be the most important foodborne parasitic infection.

An opportunity for One Health: A One Health approach with collaboration between the human and health sectors is warranted for a rapid and sustained reduction in *T. solium* prevalence.

Rationale 3: Investing in collaboration and integration can lead to rapid advances and improvements in health beyond control of *T. solium*

Collaboration: International decisions, collaboration and surveillance are needed to support the wide-scale reduction of *T. solium* globally. Successful control of *T. solium* infection requires collaboration among various sectors within endemic countries and must be driven from within affected countries. Collaboration among the health, veterinary, agricultural, academic, governmental and nongovernmental sectors is vital

to ensure that appropriate control programmes are planned and implemented.

Integration: Opportunities exist to combine control of *T. solium* with that of other neglected tropical diseases programmes or other production limiting diseases in pigs for optimized, cost-benefiting interventions.

1. Overview

T. SOLIUM IS A NEGLECTED TROPICAL DISEASE WITH IMPORTANT PUBLIC HEALTH IMPLICATIONS

Taenia solium, a zoonotic tapeworm endemic in Latin America, South and South-East Asia and parts of sub-Saharan Africa, causes two distinct diseases: cysticercosis and taeniasis. Taeniasis refers to intestinal infection with adult tapeworms, while cysticercosis is the development of larval cysts in the tissues, eyes and brain of humans. Neurocysticercosis, the infestation of the cysts in the central nervous system is the leading cause of preventable epilepsy worldwide (WHO, 2015a).

Porcine cysticercosis occurs when pigs ingest *T. solium* eggs, whose larvae form small cysts throughout their body. Consumption of undercooked pork from infected animals leads to the development of adult tapeworms in the small intestine of humans, the so-called taeniasis. If left untreated the tapeworm can survive inside the body for many years, producing large numbers of eggs (< 30 000 a day) that are expelled in human faeces. These can contaminate the environment and again infect both pigs and humans.

Human cysticercosis results as a consequence of bad personal hygiene, when people ingest the tapeworm eggs excreted by human taeniasis carriers. These develop into larvae, form cysts and lodge in the muscles, skin and eyes. If larvae invade the central nervous system the infection leads to neurocysticercosis, and can cause seizures, epilepsy, further neurological symptoms and death (WHO, 2014).

Neurocysticercosis is the leading cause of preventable epilepsy worldwide (WHO, 2015a). Because of its importance for public health, *T. solium* cysticercosis was added by WHO to the list of neglected tropical diseases (NTD) in 2010. The WHO Member States called for coordinated action to address the health, social and public knowledge implications of epilepsy through a resolution endorsed at the 68th World Health Assembly in May 2015. In 2015, the WHO Foodborne disease burden Epidemiology Reference Group identified *T. solium* as a leading cause of deaths from food-borne diseases, resulting in a considerable total of 2.8 million disability-adjusted life-years (DALYs).

Tools are available to facilitate the control of *T. solium* in humans and animals. These include health education, improved sanitation, improving pig farming practices, porcine vaccination, improved meat inspection and processing, and anthelmintic medicines for use in humans and pigs. These approaches require interdisciplinary collaboration at a local, national and global level to optimize human, animal and environmental health (Bank, 2012). Collaboration, surveillance and integration of resources within countries and internationally are necessary to the control of *T. solium*.

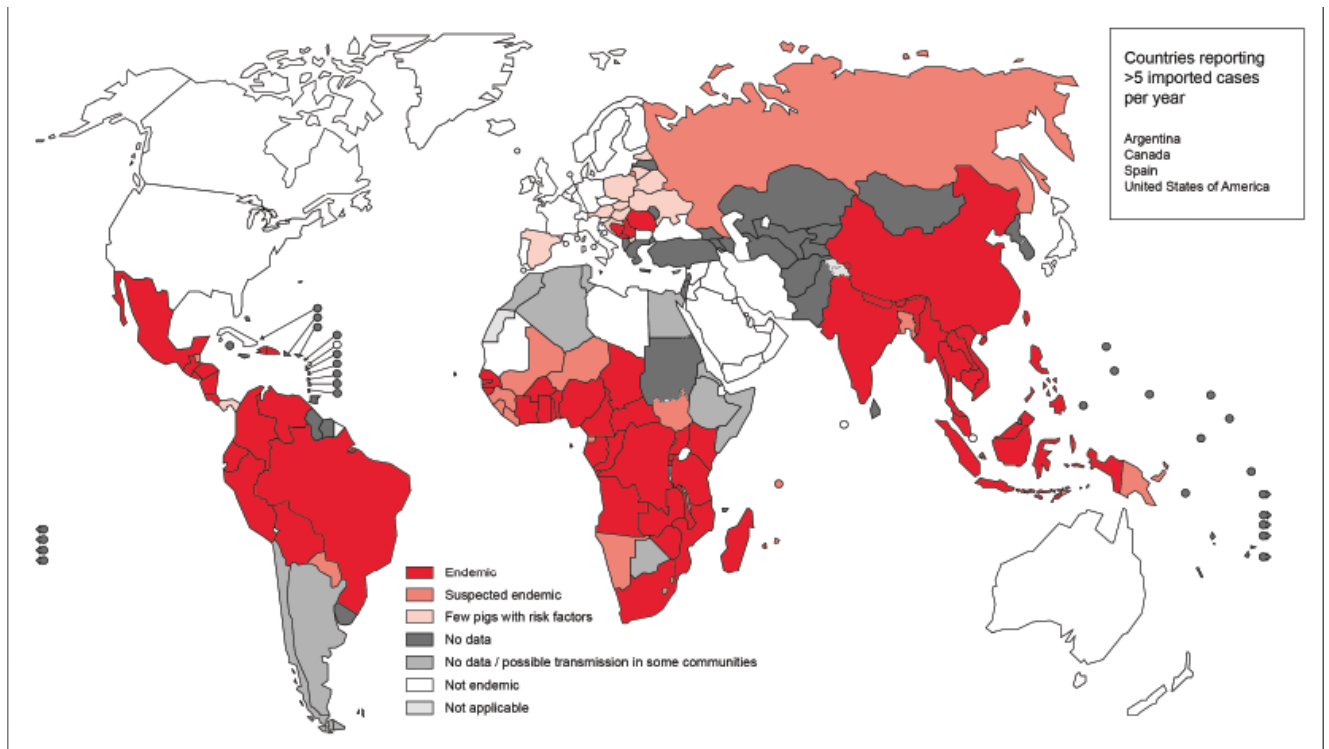
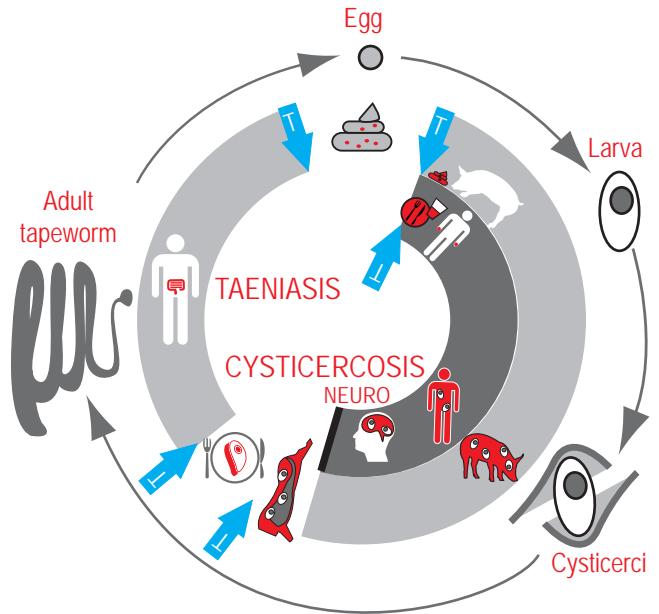
T. solium infection affects the health and livelihoods of poor, rural farming communities in developing countries where sanitation is poor and traditional free range pig farming methods are used. These factors allow pigs to ingest human faecal material that may contain infective *T. solium* eggs (WHO, 2014).

Although theoretically preventable, a lack of awareness and understanding about the conditions leading to *T. solium* infection has contributed to the neglect of this disease, which mainly affects the poorest populations of the world.

Successful control of *T. solium* requires collaboration among various sectors within endemic countries, such as medical and veterinary public health, education, food safety, sanitation and environment.

International decisions, collaboration and surveillance are needed to support the wide-scale reduction of *T. solium* globally.

Opportunities exist to combine control of *T. solium* with that of other neglected tropical diseases or other production-limiting diseases in pigs for improved, cost-benefiting interventions.



Endemicity of *Taenia Solium*, 2015

2. Evidence to support investment in the control of *T. solium* infection

In Peru, symptoms of neurocysticercosis have been estimated to cause the average sufferer a loss of 44.5 hours of productive activity per month.

Such symptoms cause two-thirds of wage-earners to lose their jobs, and only 61% are able to re-engage in wage-earning activities.

Annual losses due to porcine cysticercosis have been estimated at about US\$ 25 million for 10

West and Central African countries in 2002 and of US\$ 5 million for the Eastern Cape Province of South Africa in 2004.

Porcine cysticercosis has a serious impact on pig-producing communities, leading to poor-quality pork, falling pork prices or pork being condemned as unfit for human consumption, thereby reducing income and rendering an important source of protein unsafe to eat.

Rationale 1: *T. solium* infection is a serious yet under-recognized public health concern and especially affects poor people in rural farming communities.

Neurocysticercosis is responsible for about 30% of epilepsy cases in endemic countries and 3% globally (Ndimubanzi et al., 2010). Where access to health services is limited, mortality due to neurocysticercosis is around 3–6 times higher than in the general population (WHO, 2015a).

Diagnosis of suspected neurocysticercosis currently requires computed tomography (CT) scans. These facilities are not readily available in most rural areas where the disease is most prevalent, making it difficult to identify and treat patients.

This parasite impacts the health and livelihoods of poor people in rural farming communities where sanitation is poor and traditional, free-range pig farming methods are used. The combination of these factors allows pigs to ingest human faecal material

NEUROCYSTICERCOSIS IS AN IMPORTANT AND PREVENTABLE CAUSE OF EPILEPSY WHICH CREATES BURDEN THROUGH STIGMATIZATION, INCAPACITATION AND LOSS OF WORK PRODUCTIVITY.

potentially containing infective *T. solium* eggs, perpetuating the life-cycle (WHO, 2014).

The burden of *T. solium* impacts the poorest members of society who are disproportionately affected by neurocysticercosis and who suffer losses to their livelihoods should infected pigs be detected at slaughter and condemned.

Developed nations are increasingly burdened by neurocysticercosis. Imported taeniasis cases lead to indigenously acquired cases by citizens. It can

also pose a problem among refugees with clinical or subclinical neurocysticercosis requiring diagnosis, treatment and support (O'Neal et al., 2012; Sorvillo, DeGiorgio & Waterman, 2007).

Neurocysticercosis is an important and preventable cause of epilepsy which creates burden through stigmatization, incapacitation and loss of work productivity.

Rationale 2: Control of *T. solium* is possible with investment in existing tools.

TOOLS AND APPROACHES ARE AVAILABLE TO FACILITATE THE CONTROL OF *T. SOLIUM* IN HUMANS AND ANIMALS. THEY REQUIRE INTERDISCIPLINARY COLLABORATION AT A LOCAL, NATIONAL AND GLOBAL LEVEL.

Health education

Health education campaigns can focus on the biology of the disease, improvements in meat preparation and hygiene, the need for adequate sanitation or on improved pig husbandry. These can be targeted at the general population, health workers or pig farmers and meat workers.

T. solium health education tools, including open access information and advocacy tools, have been developed (Johansen et al., 2014) and are an essential compo-

7 —
nent of community sensitization before implementation of mass drug administration programmes. Although the long-term efficacy of health education as a standalone strategy for control of *T. solium* has yet to be demonstrated (Thomas, 2014), promising results from a collection of studies demonstrate an increased awareness of the parasite and improvement in certain key practices such as a reduction in the consumption of infective pork (Ngowi et al., 2009; Ngowi et al., 2007a; Ngowi et al., 2008), improved hand-washing (Alexander et al., 2012) and reduced numbers of free-roaming pigs (Wohlgemut et al., 2010; Sarti, Schantz & Flisser, 1998; Sarti et al., 1997).

Such behavioural changes may reduce the prevalence of *T. solium* in the long-term by disrupting its life-cycle although this has not been demonstrated in a trial situation.

BEHAVIOURAL CHANGES MAY REDUCE THE PREVALENCE OF *T. SOLIUM* IN THE LONG-TERM BY DISRUPTING ITS LIFE-CYCLE

Human preventive chemotherapy

Preventive chemotherapy involves the distribution of drugs at regular intervals to at risk human populations in order to destroy parasitic worms. It can be implemented in three ways:

1. Mass drug administration treats the entire population of a predefined geographical area at regular intervals, irrespective of individual clinical status. This approach has successfully reduced transmission of *T. solium* over a 6–9 year time-frame (Wu et al., 2012; Pawlowski, Allan & Sarti, 2005; Data indicate that some short-term success can also be achieved (Thomas, 2014).

2. Targeted chemotherapy treats specific risk groups irrespective of individual clinical status.

3. Selective chemotherapy screens and treats infected and suspected infected individuals (Gabielli et al., 2011). This option may be suitable where a strong primary health network covers > 70% of the at-risk population (Sarti & Rajshekhar, 2003). Although no evidence is available of its effect as a standalone strategy against *T. solium* transmission, selective treatment of schoolchildren combined with mass drug administration has significantly reduced neurocysticercosis as an etiology of epilepsy reported after the intervention (Medina et al., 2011).

Three essential anthelmintic medicines are safe, effective and readily available for treatment of *T. solium* infection in humans: praziquantel (10 mg/kg), niclosamide (2 g/person) and triple-dose albendazole (400 mg) (Thomas, 2014). Preventive chemotherapy may enable the control of *T. solium* infection to be combined with that of other neglected tropical diseases such as schistosomiasis and soil-transmitted helminthiasis depending on the medicine and dosage selected.

Chemoprophylaxis and vaccination in pigs

Chemoprophylaxis in pigs has been widely used as a control strategy with demonstrated high efficacy in protecting pigs from cysticercosis (Assana et al.,

FORTUNATELY, PIGS CAN NOW BE TREATED WITH ANTI-PARASITIC MEDICATIONS AND VACCINATED AGAINST *T. SOLIUM*. THIS PREVENTS THE PARASITE FROM BEING TRANSMITTED TO HUMANS.

2013). Commercialization of the TSOL18 vaccine has led to the development of a scalable, economically viable pilot vaccine that has proven effective in protecting pigs from cysticercosis. Use of the vaccine together with oxfendazole treatment of pigs can greatly reduce the transmission of *T. solium* from pigs to humans (Thomas, 2014).

Improved sanitation

Ensuring that sanitation facilities are available and used has public health advantages beyond *T. solium* control, notably the prevention of diarrhoeal diseases (Bulaya et al., 2015). A recent study modelling the transmission dynamics of *T. solium* indicated that improved sanitation can decrease the prevalence of infections in humans and pigs (WHO, 2015b). However, practical evidence is not available on the efficacy of sanitation initiatives for *T. solium* control (Thomas, 2014; which may result from cultural barriers to the use of latrines (Bulaya et al., 2015).

TO PREVENT CONTACT BETWEEN PIGS AND INFECTIVE FAECAL MATERIAL, EITHER PIGS CAN BE PREVENTED FROM SCAVENGING OR PEOPLE CAN BE PREVENTED FROM OPENLY DEFECATING.

Pig farming practices

Neurocysticercosis occurs in countries where families engage in community farming practices and raise free-roaming pigs. It is also common in areas where animals are slaughtered outside approved abattoirs and in the absence of meat inspections.

Encouraging farmers to adopt better farming practices, specifically by confining pigs to prevent their access to human faecal material, is consistently included in recommendations for *T. solium* control (Penrith et al., 2009; European Commission, 2000; Fleury et al., 2013).

In areas where pigs are routinely confined, cysticercosis has not been detected (Flisser et al., 2003). The increase in pig confinement was thought to be responsible for some of the reduction of porcine cysticercosis prevalence found in a Mexican study (Sarti et al., 1997).

Improved pig husbandry is considered integral to long-term control strategies (Murrell, 2005; Enander et al., 2010) and can also protect pigs from African swine fever, a serious disease of economic importance to pig farmers in some regions (Thomas et al., 2013).

T. SOLIUM INFECTION IS NOT JUST LIMITED TO RURAL AREAS OR DISADVANTAGED COMMUNITIES LACKING BASIC SANITATION. A GROWING CONCERN IS THE LACK OF HYGIENE PRACTICES AMONG FOOD HANDLERS WHERE THE PRACTICE OF REGULAR HAND-WASHING IS IMPORTANT.

Meat inspection and processing

The aim of meat inspection is to break the life-cycle of *T. solium*, considered to be the most important foodborne parasitic infection (FAO/WHO, 2014). The detection and condemnation of infected carcasses reduces the risk of humans consuming pig meat containing viable cysticerci (larval cysts of *T. solium*). Stringent meat inspection has been integral in controlling the transmission of *T. solium* in many developed nations (Zammarchi et al., 2013; Murrell, 2005). However, meat inspection is known to be insensitive, especially in low cyst burdens (Garcia et al., 2007; Dorny et al.,

ENSURING CORRECT PROCESSING OF MEAT REQUIRES SUCCESSFUL HEALTH EDUCATION PROGRAMMES RESULTING IN EFFECTIVE AND SUSTAINED BEHAVIOUR CHANGE.



2004). The presence of informal markets where meat is not inspected before sale is a barrier to effective implementation in many endemic settings (Garcia et al., 2007; Ngowi et al., 2007a; O'Neal, Winthrop & Gonzalez, 2011).

An opportunity for One Health collaboration

The programmes undertaken in Peru demonstrate that veterinary and human health teams can work together successfully towards *T. solium* control in a One Health Approach.

A sustainable strategy targeting both humans and pigs may yield rapid, sustained reductions in parasite prevalence (Garcia et al., 2006). Previous modelling work has identified such a combined approach as the most effective (Kyvsgaard, Johansen & Carabin, 2007).

An expert consultation (Lao People's Democratic Republic, 2009) outlined a One Health package for *T. solium* control. The core intervention is treatment of taeniasis cases (through mass drug administration or

selective chemotherapy) combined with mass treatment and vaccination of pigs, as is being undertaken in Peru and has been recommended elsewhere (WHO, 2011; Mahanty & Garcia, 2010; Enander et al., 2010). The expert consultation suggested that this core approach be supplemented by specific health education programmes and followed by those measures requiring fundamental social changes including improved meat inspection, improved husbandry and improved sanitation.

SUCCESSFUL CONTROL OF *T. SOLIUM* REQUIRES COLLABORATION AMONG VARIOUS SECTORS SUCH AS MEDICAL AND VETERINARY PUBLIC HEALTH, EDUCATION, FOOD SAFETY, SANITATION AND ENVIRONMENT.

Rationale 3: Investing in collaboration and integration can lead to rapid advances in control of *T. solium* infection and beyond.

Collaboration

Control of *T. solium* infection must be driven from within affected countries. Collaboration among the health, veterinary, agricultural, academic, governmental and nongovernmental sectors is vital to ensure that appropriate control programmes are planned and implemented. The Kenya Zoonotic Disease Unit is an example of successful intersectoral collaboration. Examples of collaborations for *T. solium* control are the

WHO IS WORKING WITH COUNTRIES TO TAILOR INTENSIFIED CONTROL STRATEGIES FOR *T. SOLIUM* AND IMPROVE MANAGEMENT OF NEUROCYSTICERCOSIS PATIENTS.

Peruvian (Schantz, 2006) and Indonesian (Suroso et al., 2006) working groups on cysticercosis.

Integration

The many regional alliances between researchers should continue to be supported to ensure continued networking and dissemination of lessons learned. Open communication between networks and international authorities should be encouraged (Fleury et al., 2013).

Neglected tropical disease programmes or national primary health-care integration

The integration of *T. solium* control with other neglected tropical disease control programmes or within national primary health care systems has been discussed extensively (WHO, 2013; Bockarie et al., 2013; Budke, White Jr & Garcia, 2009; Buse & Walt, 1997; Rasamoelina-Andriamanivo, Porphyre & Jambou, 2013; Mackey & Liang, 2012; Hotez, 2009; Gemmell, 1987; Baker et al., 2010; WHO, 2007; Utzinger et al., 2012; Utzinger et al., 2009; Nakagawa et al., 2013; Hotez et al., 2008; Hopkins, 2009, Gyapong et al., 2010; Lekule & Ngowi, 2010).

Several papers have reviewed the requirements and challenges for implementing integrated programmes and a reasonably comprehensive framework has been proposed. Considerations include ensuring government commitment, performing a situation analysis including leveraging synergy between different programmes (both vertical and horizontal), defining monitoring and evaluation strategies including the need to monitor drug resistance and defining the endpoint for interventions (Bockarie et al., 2013; Hanson et al., 2012; Allotey, Reidpath & Pokhrel, 2010; Amazigo et al., 2012).

Control of *T. solium* may also be integrated within other animal health programmes such as vaccination programmes for production-limiting diseases. For ex-

ample, the possibility of combining the TSOL18 vaccine with that for classical swine fever in central and South America has been discussed (Lightowers, 2010).

OPPORTUNITIES EXIST TO COMBINE CONTROL OF *T. SOLIUM* WITH THAT OF OTHER DISEASES FOR IMPROVED, COST-BENEFITING INTERVENTIONS.

3. Country case examples

Controlling neglected tropical diseases of animals and humans such as *T. solium* infection contributes to the alleviation of poverty (Molyneux et al., 2011), although countries in which cysticercosis is endemic struggle to control this disease. The complex life-cycle of the *T. solium* parasite causes intense physical and economic suffering in resource-poor countries. To control *T. solium*, investment is required to break its complex life-cycle (Maurice, 2014).

Case examples from Madagascar, Mexico and the United Republic of Tanzania, derived from ‘Results Flow Logic’ (HKIS, 2015), identify for each country programme lessons, context and funding requirements. (A table of goals and outcomes for each country is annexed to this document).

MADAGASCAR¹

Lessons identified

- **Diagnosis and treatment programmes are expensive and limited.** Fewer than 10 computer tomography scans are available, making access to diagnosis inaccessible for many (MINSANTE, 2015; Rasamoelina-Andriamanivo, Porphyre & Jambou, 2013). Diagnosis and treatment of cysticercosis are expensive (MSANP, 2014). There is little financial support for programme activities.
- **Cysticercosis is poorly understood.** Lack of understanding of cysticercosis in medical doctors and the general population results in a lower rate of detection of existing cases. Cysticercosis is not currently included in programmes against “dirty-hands diseases”. Messages about cysticercosis need to be included in all sensitization activities promoting hygiene and sanitation (MSANP, 2015).
- **Diagnosis, treatment and veterinary legislation are not standardized.** Diagnostic and treatment procedures for patients suspected of having cysticercosis vary depending on medical doctors, and veterinary oversight for prevention is limited (MSANP, 2015).
- **Multisectoral collaboration is weak.** Multisectoral collaboration between human and veterinary public health must be intensified, sustainable and operational.
- **Application of veterinary legislation is deficient.** The application of veterinary legislation by meat inspectors in slaughterhouses is deficient (MSANP, 2015).
- **Barriers exist to an integrative strategy.** Despite an existing national strategy for the control of cysticercosis in Madagascar there are barriers to scaling it up to the whole country (WHO, 2015b). Previous *T. solium* control interventions have focused mainly on people, with disappointing results (Maurice, 2014). An integrated cysticercosis detection strategy for both humans and pigs is essential to controlling the disease. There is little financial support for programme activities. An integrated strategy of health education, improved sanitation, improved meat inspection, pig farming practices and mass drug treatment of humans is needed to control and disrupt the life-cycle of the parasite (Rasamoelina-Andriamanivo, Porphyre & Jambou, 2013; MSANP, 2015). All strategies must be based on the results of operational research specific to the local context, and indicators calculated and evaluated to follow-up the efficiency of each activity (surveillance, training, treatment, etc.) (MSANP, 2015).

¹ June 2015 WHO Madagascar. Unless referenced otherwise, the country information for *T. solium* in Madagascar was reviewed and provided by Dr Sylvia Ramiandrasoa, Ministère de la santé, Contrôle et coordination de la lutte, Madagascar and Dr Michel Rakotoharinome, Vétérinaire Epidémiologiste, Direction des Services Vétérinaires, Madagascar.

Context

Cysticercosis is emerging as a serious public health issue in Madagascar. It is endemic largely due to the persistence of traditional free range pig husbandry practices, lack of knowledge about the disease and general poor hygiene. Studies carried out by the Madagascar Ministry of Public Health and the Institute Pasteur of Madagascar have reported a sero-prevalence of human cysticercosis ranging from 7% to 21% (Andriantsimahavandy et al., 2003). A study conducted in 34 Malagasy districts in 2010–2014 to investigate schistosomiasis through Kato-Katz method found that 23 districts had cases of *T. solium* infection (MINSANTE, 2015). The Ministry of Health reported 5204 suspected cases of neurocysticercosis (in 2013) and 4145 suspected cases (in 2014) in 112 districts (Rapports mensuels d'activité des formations sanitaires de base 2013–2014) (MSANP, 2015).

Information on the economic impact of porcine cysticercosis in Madagascar is limited. A study in 2012 estimated the direct costs at around US\$ 14 million per year (Andriamparany, 2012). Losses are incurred by pig farmers through condemnation of infected carcasses at formal slaughterhouses or through reduced sale value (20–50% loss) for infected carcasses sold illegally. A cysticercosis prevalence of 22% in pigs has been found in the rural areas and 15% in periurban areas (WHO, 2015b). These figures are significantly higher than the 'official' prevalence reported in 2002–2009 of 1.1% on average (ranging from 0.03% to 8.9% depending on the region) in pork carcasses inspected at formal slaughterhouses (Direction des Services Vétérinaires; MSANP, 2015; Rakotoharinome, 2015). The disparity in these figures questions the reliability of the surveillance system in Madagascar as currently implemented (WHO, 2015b).

Diagnostic tools, are available only in large cities. For example, even in the capital city Anananarivo only a small proportion of people who need neuroimaging for neurocysticercosis diagnostics can access this technique because of its expense (WHO, 2015b).

Investing in control

- **Framework for action and standardized protocols.** Prepare an action framework supported by WHO/FAO/OIE. Design a standardized monitoring and evaluation protocol for Madagascar-specific *T. solium* control programmes (WHO, 2015b).
- **Surveillance data.** Conduct a baseline survey to determine national prevalence (of taeniasis and cysticercosis), porcine cysticercosis and variability of *T. solium* infection and associated risk factors among regions (WHO, 2015b; MSANP, 2015).
- **Burden of disease data.** Determine (i) the burden of human cysticercosis and taeniasis; (ii) the importance and constraints of pig farming in different settings (urban, rural, etc.); (iii) the cost-effectiveness of intervention options (potential economic gains from improved pig management, conditions for long-term adoption of new practices by farmers and stakeholders); and (iv) evaluate communication media (MSANP, 2015).
- **Diagnosis and treatment capacity.** Improve country capacity and availability for diagnosis and treatment of cysticercosis and neurocysticercosis and improve decentralized treatment of epilepsy at the primary health-care level. Develop accessible diagnostic tools for use (i) at the farm gate, to detect infected pigs and prevent trade of infected meat; (ii) in humans in all health-care centres; and (iii) in prevalence surveys (MSANP, 2015).
- **Pig treatment and vaccination.** Include treatment (with oxfendazole) and vaccination (using TSOL18) of pigs initially within pilot programmes and, depending on the results, expand nationally (MSANP, 2015).
- **Preventive human chemotherapy.** Extend preventive chemotherapy against taeniasis to those districts not covered through schistosomiasis control (WHO, 2015b).

MEXICO¹

Lessons identified

- **Knowledge of the *T. solium* life-cycle** is sufficient. The reduction in the number of cases and number of pigs condemned suggests that lack of knowledge of *T. solium* does not represent a major problem in Mexico (Flisser, 2015).
- **Restraining pigs increases their economic value.** Restraint of pigs in settings without access to human faeces or waste reduced disease and increased sale prices of animals (Flisser, 2013).
- **Sustainable long-term educational strategies and outcomes are difficult to ascertain.** Any sustainable effect between educational strategies and changes in behaviour are difficult to ascertain, particularly in short-term interventions (WHO, 2012).

Context

National guidelines for the surveillance, prevention and control of taeniosis/cysticercosis were published in 1994 and revised in 2004 (WHO, 2011) to establish prevention and control measures for taeniosis and human and porcine cysticercosis in the population (Flisser & Correa, 2010). These include three main strategies for prevention and control: (i) education; (ii) social participation; and (iii) epidemiological surveillance (Department of Health, 1994).

'Hot spots' of cysticercosis are endemic in the Mexican provinces of Guanajuato, Guerrero, Morelos, Puebla and Yucatan (WHO, 2011). Some 60% of Mexico's population live in poor and/or rural areas where a porcine cysticercosis prevalence of 32% has been reported in some communities and only about 1 June 2015 WHO Mexico.

500 cases of human neurocysticercosis have been diagnosed in the past 10 years. Lack of access to accurate neuro-imaging diagnosis by a large part of the population points to a significant underreporting of the real burden of neurocysticercosis (Fleury, Sciotto & Larralde, 2012).

Investing in control

- **Better health education to identify tapeworm carriers.** Support of the Ministry of Health to provide better health education to identify tapeworm carriers in health centres and/or infected farms (Flisser, 2015).
- **Effective communication on control measures.** Conduct studies to find ways to assure adequate communication on control measures (Flisser, 2015).
- **Improved understanding of the costs and long-term outcomes of health education.** Direct future studies at comparing the costs and long-term outcomes of health education in Mexico (Sarti et al., 1997).

¹ June 2015 WHO Mexico. The information on *T. solium* in Mexico was reviewed by Dr Ana Flisser, President of ICOPA XIII 2014, Coordinadora del PECEM, Facultad de Medicina, Universidad Nacional Autónoma de México, Faculty of Medicine, National University of Mexico.

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Lessons identified

- **Not confining pigs generates risk, and poverty hampers confinement.** Free-range and semi-confinement systems of pigs increases the risk of porcine cysticercosis (Komba et al., 2013) as so far, confinement in the absence of other societal changes has proved ineffective in preventing the infection (Braae et al., 2014). Similarly, poverty can hamper pig confinement because additional labour and animal feed are required (Lekule & Ngowi, 2010).
- **Porcine cysticercosis burdens smallholder pig farmers.** The burden of porcine cysticercosis to public health and the economy is greatest on smallholder pig farmers where pigs are produced, and in urban centres where rural pigs are marketed (Komba et al., 2013).
- **Pork slaughter facilities and meat inspection practices are inadequate.** Policies and guidelines should be prepared aimed at improving pig husbandry practices, meat inspection for porcine cysticercosis, and slaughtering and marketing channels to increase inspection of pork consumed. Adequate numbers of slaughter facilities should be established and a reasonable number of qualified inspectors allocated especially in underserved rural areas (Lekule & Ngowi, 2010).
- **Local authorities are unable to enforce current legislation, and technical ministries should be supported to safeguard public health.** To safeguard public health, local government and ministries should support enforcement of cysticercosis control by local councils (Lekule & Ngowi, 2010).
- **Target health education messages at schoolchildren.** Control of *T. solium* cysticercosis and taeniasis is feasible in endemic areas by targeting health messages at schoolchildren (Mwidunda et al., 2015) and can be considered with other school based programmes such as deworming treatment.

Context

In Tanzania, cysticercosis is a serious zoonotic disease that warrants urgent national attention and intersectoral collaboration (Lekule & Ngowi, 2010). Surveys of human and porcine cysticercosis provide preliminary evidence that the parasite is widespread in almost all regions (Boa et al., 1995; Boa et al., 2006; Braae et al., 2014; Mwanjali et al., 2013; Ngowi et al., 2004; Winkler et al., 2009). In the Mbulu district of Manyara Region the reported prevalence of human cysticercosis was 16.4% (95% CI [confidence interval], 13.3–19.7) using the IgG western blot assay (Mwang'onde, Nkwengulila & Chacha, 2012) while in the same region the proportion of neurocysticercosis-associated epilepsy was 16.6% (95% CI, 11.8–22.2) (Blocher et al., 2011).

A recent (2015) study has confirmed the importance of integrating *T. solium* control with other programmes such as schistosomiasis. The distribution of *T. solium* and schistosomiasis in Africa between 1985 and 2014 was mapped, confirming the presence of *T. solium* in the United Republic of Tanzania during this time period. In all African countries where *T. solium* occurred, including in the United Republic of Tanzania, mass drug administration was also recommended for the control of schistosomiasis. The study recommended that in areas where these two helminth infections are co-distributed, emphasis on evaluating an integrated intervention approach should be increased (Braae et al., 2015).

Stigmatization has damaging personal, familial and social consequences and is reported to result from living with a condition such as epilepsy in Tanzania, (Rwiza et al., 1993), as in other countries. The association between epilepsy and *T. solium* infection in the human brain (neurocysticercosis) suggests that neurocysticercosis may be responsible for a considerable proportion of epilepsy in the United Republic of Tanzania. Controlling neurocysticercosis may therefore provide an opportunity to reduce the epilepsy burden (Lekule & Ngowi, 2010).

The current pig population of the United Republic of Tanzania is 2.01 million, of which more than 90% are kept by smallholder farmers (URT, 2012). Pig

production is a fast growing subsector. Smallholder pig farmers are most vulnerable to income loss when their porcine cysticercosis infected pigs cannot be sold or are condemned. Consumer demand for pork is increasing and pigs are thus transported from rural to urban areas, heightening the risk of transmission to areas where meat inspection is insufficient (Komba et al., 2013).

Investing in control

- **Reliable quantitative data.** Carry out surveillance and testing of suitable *T. solium* control strategies (Lekule & Ngowi, 2010) and generate reliable quantitative data on the public health burden of diseases involving humans and animals (Molyneux et al., 2011). Determine the full economic impact and adopt cost-effective *T. solium* control strategies by securing data on the frequency and burden of the disease and its impact on pig production and human health (Ngowi et al., 2007b).
- **Information on transmission, vaccination and treatment of porcine cysticercosis to design integrated *T. solium* control programmes.** Investigate through field studies the effectiveness of vaccination and pig treatment for controlling porcine cysticercosis (Lekule & Ngowi, 2010). Identify the factors responsible for transmission of porcine cysticercosis

within and outside pig pens to inform the design of integrated *T. solium* control programmes (Braae et al., 2014). Elucidate the degree and causes of seasonal fluctuations in the prevalence of porcine cysticercosis to determine optimum time-points for implementing control programmes (Braae, et al., 2014).

- **Economic burden of livestock production losses on health and poverty.** Evaluate the impact of livestock production losses on health and poverty (Molyneux et al., 2011).
- **Cross-sectoral relevance to achieve buy-in.** Obtain more information on the relevance of cross-sectoral issues in designing and implementing zoonotic public health programme interventions, with input from policy-makers to achieve added value buy-in (Molyneux et al., 2011).
- **Adoption of better *T. solium* control practices.** Develop programme interventions that empower families and communities to assume responsibility for aspects of disease control. Demonstrate community skills that enable people to adopt better *T. solium* control practices that require minimal financial inputs, using locally available natural resources (for pigpens and latrines) and skills (to store local animal feed during dry seasons) (Ngowi et al., 2009).

SUMMARY:

WHY INVESTMENT IS NEEDED

INVESTING IN HEALTH IS INVESTING IN ECONOMIC GROWTH AND THE WELL-BEING OF PEOPLE.

RATIONALE 1: *T. SOLIUM* INFECTION IS A SERIOUS YET UNDER-RECOGNIZED PUBLIC HEALTH CONCERN.

Summary of case examples supporting rationale outcomes and lessons identified

The burden to human health (from *T. solium* infection, neurocysticercosis and cysticercosis) and animals (from porcine cysticercosis and economic losses to pig farmers) is a serious public health issue in Madagascar, Mexico and the United Republic of Tanzania. Public health concerns in affected countries include rural pig farms and urban pig processing areas suffering from public health and economic burdens. Understanding and treatment of cysticercosis vary, resulting in lower case detection rates. Diagnosis and treatment are expensive and access may be limited.

RATIONALE 2: *T. SOLIUM* CONTROL IS POSSIBLE WITH INVESTMENT IN EXISTING TOOLS.

Summary of case examples supporting rationale outcomes and lessons identified

Community involvement reduces transmission of *T. solium* infection. Understanding the benefits of pig health and management would yield significant financial benefits for pig farmers. Self-detection of tapeworms to control *T. solium* infection is feasible. Latrines without doors or with slatted floors may not prevent access by roaming pigs or escaped piglets.

Cysticercosis education messages are lacking and must be included in hygiene and sanitation messaging. Although there may be value in targeting schoolchildren for health messages on *T. solium* cysticercosis and taeniasis, the sustainable effects of educational strategies and behavioural changes are difficult to confirm with short-term strategies.

Meat inspectors must learn to apply veterinary legislation in slaughterhouses. Pork inspection guidelines and policies are needed to improve pig farming and meat inspection practices. Pigs that are not able to access human faeces or waste and are not diseased sell for higher prices.

RATIONALE 3: INVESTING IN COLLABORATION AND INTEGRATION CAN LEAD TO RAPID ADVANCES AND IMPROVEMENTS IN HEALTH BEYOND CONTROL OF *T. SOLIUM* INFECTION.

Summary of case examples supporting rationale outcomes and lessons identified

Multisectoral collaboration must be intense, sustainable and operational. In 2009 taeniosis/ cysticercosis were prioritized as helminthic infections for global control. International collaboration to prepare a control strategy to reduce the burden of infection by supporting the efforts of endemic countries and to ease the epilepsy burden of the disease was initiated in 2014 and facilitated by WHO.

T. SOLIUM CONTROL WITHIN COUNTRIES: SUMMARY OF INVESTMENT NEEDED.

Local integration

- Improve country capacity and availability for diagnosis and treatment.
- Develop country public health prevalence and taeniasis and cysticercosis burden disease data involving both humans and pigs.
- Improve decentralized treatment of epilepsy at primary health-care level.
- Develop accessible diagnostic tools for farmers to detect infected pigs, in health care centres and to measure disease prevalence.
- Provide education to identify tapeworm carriers in health centres and infected farms.

- Develop programme interventions that empower families and communities to assume responsibility for disease control measures that require minimal financial inputs and are available using locally available natural resources and skills.
- Evaluate the relevance of cross-sectoral issues in designing and implementing public health programme interventions.

T. solium surveillance, strategies and associated risk factors

- Evaluate the economic impact and cost-effectiveness of various *T. solium* control strategy intervention options, including the impact of livestock production losses on health and poverty.
- Determine the regional and seasonal variability of *T. solium* and associated risk factors such as the importance of different pig farming constraints in different settings including risk factors for porcine cysticercosis transmission within and outside pig pens.
- Develop and ensure adequate communication of control measures and strategies.
- Standardize the monitoring and evaluation of *T. solium* control programmes.

HEALTH IS LIKELY ONE OF THE MOST PRECIOUS COMMODITIES IN LIFE. BUT IT IS HIGHLY POLITICAL AND IT REQUIRES INVESTMENT. YOU NEED POLITICAL LEADERSHIP. YOU NEED COMMITMENT. AND YOU NEED A CONVERSATION

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Annex. Country goals and outcomes

A1.1 MADAGASCAR RESULTS FLOW LOGIC¹

Goal

Reduce the high risk of contracting human infection in order to reduce the prevalence of human cysticercosis to less than 10% and intensify control of human taeniasis

Results flow logic (HKIS, 2015)

Programme strategy	Programme objectives ²	Programme activities ³	Change outcomes (short-, intermediate- and long-term and health impact)
1. Increased collaboration and partnerships	1. Develop multisectoral partnerships and collaborations	1. Veterinary services 1. NGOs included in sanitation project Research Centre	1. <i>Taenia solium</i> infection included in integrated national plan for control of neglected tropical diseases in 2007 and 2014 (MSANP, 2015) 1. Meeting of Ministry of Health and WHO NTD Department to revitalize prevention and control strategy (MSANP, 2015)
2. Improved diagnosis and treatment	2. Implement a medical prophylaxis programme in animals (vaccination and deworming) and humans (mass drug administration)	2. Provide preventive chemotherapy for <i>T. solium</i> infection (PZQ)	2. Treatment of 121 678 children with anthelmintic medicines (WHO, 2015b; MSANP, 2014)
3. Enhanced prevention	3. Train all agents involved in public and veterinary health for prevention and control of cysticercosis as well as management of patients with cysticercosis 3. Strengthen social mobilization to prevent and control <i>T. solium</i> infection	3. Social mobilization to promote hand, food and toilet sanitation 3. Sanitation programmes alongside training to increase public, health workers and decision-makers' knowledge of <i>T. solium</i>	3. Training of 375 health workers and 741 local decision-makers (WHO, 2015b; MSANP, 2014) 3. Increase in rate of toilet usage by population from 42% in 2012 to 48.5% in 2014 (WHO, 2015b) 3. Implementation of large health education programme comprising posters, books, radio and TV programmes (WHO, 2015b; MSANP, 2014)

NGO, nongovernmental organization; PZQ, praziquantel; NTD, neglected tropical diseases

¹ June 2015. Unless referenced otherwise, the country information on *T. solium* infection was reviewed and provided by Dr Sylvia Ramiandrasoa, Ministère de la santé, Contrôle et coordination de la lutte, Madagascar and Dr Michel Rakotoharinome, Vétérinaire Epidémiologiste, Direction des Services Vétérinaires, Madagascar.

² MSANP, 2015

³ MINSANTE, 2005; MSANP, 2014

A1.2 MEXICO RESULTS FLOW LOGIC¹

Goals

- I. Education to prevent taeniosis/cysticercosis (Department of Health, 1994)
 1. Promote health education to control *T. solium* infection (Sarti et al., 1997)
 2. Evaluate education *T. solium* strategy (Sarti, Schantz & Flisser, 1998)

- II. Social participation to prevent and control taeniosis/cysticercosis (Department of Health, 1994)
 3. Prevent and control taeniosis and human/porcine cysticercosis in Mexico (Flisser & Correa, 2010)
 4. Self-identify tapeworm carriers to control human neurocysticercosis (Flisser et al., 2005)
 5. Interrupt transmission of neurocysticercosis (Sarti et al., 2000)

Results flow logic (HKIS, 2015)

National guideline strategy by research goals	Research objectives	Research activities	Research outcomes
National strategy: education to prevent taeniosis/cysticercosis (Department of Health, 1994) 1. Promote health education to control <i>T. solium</i> infection (Sarti et al., 1997)	1. Promote recognition and knowledge of parasite transmission and improve hygienic behaviour and sanitary conditions fostering transmission (Sarti et al., 1997)	1. Effects of educational intervention evaluated by measuring changes in knowledge and practices as well as in prevalence of human taeniasis and swine cysticercosis before and after the campaign (Sarti et al., 1997)	1. Health education reduced opportunities for transmission: community involvement in health education reduced opportunities for transmission of <i>T. solium</i> in the human-pig cycle; statistically significant improvements in knowledge, life-cycle and human transmission of parasite found; behavioural changes related to transmission less dramatic and persistent, and accompanied by significant reductions in reported access of pigs to sources of infection and freedom to roam (Sarti et al., 1997)

2. Evaluate education on <i>T. solium</i> strategy (Sarti, Schantz & Flisser, 1998)	2. Evaluate <i>T. solium</i> control strategies in rural communities (Sarti, Schantz & Flisser, 1998)	2. Intervention study to evaluate control strategies against <i>T. solium</i> infection conducted in three rural communities: in Atotonilco mass PZQ treatment (5 mg/kg, single dose); in Chalcatzingo health education; and in Tetelilla both intervention strategies (Sarti, Schantz & Flisser, 1998).	2. Education and treatment needed: PZQ treatment for swine cysticercosis without education had no significant change; human taeniosis reduced by 56% when education delivered without taeniocidal treatment suggesting that adequate educational programmes are effective for <i>T. solium</i> control (Sarti, Schantz & Flisser, 1998)
National strategy: social participation to prevent and control taeniosis/cysticercosis (Department of Health, 1994) 3. Prevent and control taeniosis and human/porcine cysticercosis in Mexico (Flisser & Correa, 2010)	3. Establish prevention and control criteria and strategies (Flisser & Correa, 2010)	3. Hundreds of thousands of pamphlets with basic guideline information targeted to different populations (pig breeders, butchers, cooks, food stand workers, general population) prepared by Ministry of Health and distributed throughout the country by personnel in charge of promoting <i>T. solium</i> control (Flisser & Correa, 2010)	3. Increase in human cysticercosis notifications: increases occurred after the Mexican national guidelines were published and implemented; 584–691 cases pre-1994 compared with 1608 cases reported in 1995 (Flisser & Correa, 2010)
4. Self-identification of tapeworm carriers to control human neurocysticercosis (Flisser et al., 2005)	4. Evaluate tool for self-identification of tapeworm carriers (Flisser et al., 2005)	4. Tool to self-identify tapeworm carriers for neurocysticercosis control activities included <i>T. solium</i> infection training, instructional materials, information provided to general population, animal health-care practitioner visits to abattoirs and local markets, and informative talks (Flisser et al., 2005)	4. Increased recording of tapeworm carriers: six times more tapeworm carriers recorded one year after study implementation; increased recording of tapeworm carriers demonstrated feasibility of self-detection for <i>T. solium</i> control (Flisser, 2013; Flisser et al., 2005)
5. Interrupt transmission of neurocysticercosis (Sarti et al., 2000)	5. Evaluate the effects of single mass taeniocidal treatment on interrupting transmission from humans to pigs and other humans (Sarti et al., 2000)	5. Mass treatment against taeniosis to prevent neurocysticercosis due to <i>T. solium</i> in a rural community during 1991–1996 (Sarti et al., 2000)	5. Mass chemotherapy reduced human taeniosis: 87% of population received taeniocidal PZQ treatment to control cysticercosis, with demonstrated 53% reduction at 6 months and 56% reduction of human taeniosis recorded after PZQ treatment (Sarti et al., 2000)

PZQ, praziquantel

¹ June 2015. The country information on *T. solium* infection in Mexico was reviewed by Dr Ana Flisser, President of ICOPA XIII 2014, Faculty of Medicine, National University of Mexico.

A1.3 UNITED REPUBLIC OF TANZANIA FLOW LOGIC¹

Goals

1. Societal cost and burden research Assess the burden (societal cost) of *T. solium* infection.
2. Control strategies in both humans and pigs research Evaluate (One Health) approaches to control *T. solium* cysticercosis in humans and pigs.

Results flow logic (HKIS, 2015)

Research goals	Research objectives	Research activities	Research outcomes
1. Societal cost and burden research: assess the burden (societal cost) of <i>T. solium</i> infection	1. To determine prevalence and associated risk factors for porcine cysticercosis in smallholder pig production systems in Mbeya Region in order to provide inputs necessary for developing sustainable control strategies (Komba et al., 2013)	1. Pig production systems and pig keepers' practices evaluated to determine prevalence of and associated risk factors for porcine cysticercosis in Mbozi and Mbeya rural districts, Mbeya Region (Komba et al., 2013)	1. Prevalence of porcine cysticercosis significantly higher in shelters with slatted floors allowing pigs to escape (Komba et al., 2013) 1. Porcine cysticercosis prevalence in pig-keeper households with latrines similar to that in pig-keeper households without latrines; similarity may be attributable to latrines without closing doors and faeces on floors accessible by roaming pigs or escaped piglets (Komba et al., 2013)
	1. To describe seasonal variation in sero-prevalence of porcine cysticercosis in Mbeya Region (Braae et al., 2014)	1. Study of seasonal variations of antigen ELISA-positive cysticercosis in an endemic area (Mbeya Region) (Braae et al., 2014)	1. Confined pigs did not have lower sero-prevalence than free-roaming pigs; confinement therefore insufficient as a standalone intervention measure for preventing porcine cysticercosis in the endemic districts studied (Braae et al., 2014)

2. Research on control strategies in humans and pigs: evaluate (One Health) approaches to control <i>T. solium</i> cysticercosis in humans and pigs	2. To estimate the effectiveness of a health-education intervention against <i>T. solium</i> infection in Mbulu District on (i) reducing incidence rate of porcine cysticercosis and (ii) improving knowledge and practices related to transmission of porcine cysticercosis (Ngowi et al., 2008)	2. Study intervention and control group participants raised a sentinel piglet for 1 year to determine incidence rate of porcine cysticercosis among sentinels (Ngowi et al., 2008)	2. Another health education intervention found 43% reduction in incidence rate of porcine cysticercosis in pig-farming communities (Ngowi et al., 2008; Lekule & Ngowi, 2010)
	2. To evaluate the efficacy and safety in pigs after subcutaneous IVM injection (0.3 mg/kg) and oral OFZ administration (30 mg/kg) in treatment of porcine cysticercosis and other parasitoses in naturally infected pigs (Mkupasi et al., 2013)	2. Pigs stratified on basis of sex, age and number of cysts on tongue and randomly allocated to IVM, OFZ and control groups (Mkupasi et al., 2013)	2. Single-dose OFZ (30 mg/kg) validated and efficacious in eliminating <i>T. solium</i> cysticerci in pig muscles (Mkupasi et al., 2013)
	2. To determine the effectiveness of a health education intervention in improving knowledge and attitudes among schoolchildren of <i>T. solium</i> cysticercosis and taeniasis (Mwidunda et al., 2015)	2. Health education intervention implemented in 60 schools in Mbulu district, to improve <i>T. solium</i> knowledge and attitudes among schoolchildren (Mwidunda et al., 2015)	2. Improved knowledge and attitudes about <i>T. solium</i> transmission; overall score of schoolchildren's knowledge and attitudes on <i>T. solium</i> improved by 10% within 6 months after the research intervention (Mwidunda et al., 2015)
	2. To conduct a financial cost-benefit analysis of a health and pig management education intervention to smallholder pig farmers in Mbulu District (Ngowi et al., 2007b)	2. Analysis done from farmer's perspective; investment appraisal (simple form of benefit-cost analysis) used to analyse financial efficiency of health education intervention to smallholder pig farmers (Ngowi et al., 2007b)	2. Educating smallholder pig farmers in Mbulu district on health and pig management would yield significant financial benefit to them (Ngowi et al., 2007b)

IVM, ivermectin; OFZ, oxfendazole

¹ June 2015. The country information on *T. solium* infection was reviewed by Professor Maria Vang Johansen, Department of Veterinary Disease Biology and Aquatic Diseases, University of Copenhagen, Denmark and Dr Helena Ngowi, Sokoine University of Agriculture, Faculty of Veterinary Medicine, Department of Veterinary Medicine and Public Health, Morogoro, United Republic of Tanzania.

