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Risk factors for intestinal parasite portage in an informal suburb on the West coast of Madagascar

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A R T I C L E I N F O

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Suburb

A B S T R A C T

The deprived area of the Metzinger Valley in the city of Mahajanga has many healthcare concerns due to repeated flooding during the rainy season. Improving this health situation requires a better knowledge of the pathogens present in this area and of the risk factors favoring their propagation. The aim of this study was to analyze the relationship between the household socioeconomic status and the presence of parasites in the faeces of children between 1 and 10 years of age in order to determine the risk factors for intestinal parasitosis. The study included 746 children, of whom 30% were infected with parasites. *Entamoeba coli*, a good indicator of environmental fecal contamination, was the most prevalent parasite with an observation frequency of 16.7% followed by *Giardia lamblia* with a prevalence of 10%. For helminths, *Trichuris* and *Ascaris* were the most prevalent respectively 5.4% and 1.8%. A large heterogeneity in the prevalence of parasites was observed from one neighborhood to another. However, multivariate analysis showed that these differences were not related to environmental factors or household structure, but rather to the economic level of the family, the education level of the mother as well as the age of the child. For example, the prevalence of *Giardia* decreased from 23.5% to 8% for children of mothers with little education to those with higher education, respectively. For *E. coli*, the prevalence is higher among poor households and school-aged children. In the frame of IRCOD project, mothers are being sensitized to hygiene and risk factors for transmission by intestinal parasites and the present study proposes a multidimensional approach as an assessment tool.

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1. Introduction

Urbanization is increasing rapidly on the African continent compared to all other regions of the world. An estimate by the United Nations predicts that 68% of the African population will be urban by 2050, which represents 2.4 billion people (United Nations, 2019). This development is mainly associated with the expansion of slums and informal settlements. A rather complex system, ranging from the formation of real shantytowns made of spikes and plastic to households simply installed without an urbanization plan on the edge of the city. This causes social inequalities that will limit access to sanitation. In poor neighborhoods, the lack of environmental hygiene is one of the factors that ensure the transmission of intestinal parasites. Yet, the improvement of the standard of living significantly reduces their incidence (Benouis et al., 2013).

Intestinal parasitosis are a public health problem, affecting >2 billion people worldwide. They are particularly severe in children, where they can lead to malnutrition and anemia but also reduce resistance to infection and even increased mortality (Dianou et al., 2004). It has been estimated that over three billion people worldwide are infested with intestinal parasites (Keiser and Utzinger, 2010). It is the second leading cause of death in Africa among children who are at greater risk because of their poorly developed immune systems and their habit of playing on soil contaminated with faeces (Elliott and Weinstock, 2012).

About 24% of the world's population is infected with at least one of the following species *Ascaris lumbricoides*, *Trichuris trichiura* and *Ancylostoma duodenale.* They are the most common intestinal parasites.responsible of the death of approximately 135,000 persons per year (Liese et al., 2010). A predominance of protozoa like *E. coli* and *Giardia* in children was also reported in neighborhoods with poor sanitation (Pires et al., 2020).

Climatic conditions, poor hygiene and insufficient health education contribute to the spread of intestinal parasites (Santiso, 1997; Bouchaud and Aumaitre, 1999). The high proportion of parasitism is assumed to be combined with socio-economic factors and poor environmental hygiene within the region (Dib et al., 2012). In addition, other risk factors related to the infrastructure or living conditions of the population, such as the structure of the soil, the mother's low level of school education besides the quality of drinking water, are also potential factors for parasite infection in children living in poor areas (Habib et al., 2021). Parasite transmission also related to the number of people per household (Berzalim, 2010; Benouis et al., 2013), and villages located in flood-prone areas are more vulnerable (Dianou et al., 2004). This is the case of « Metzinger valley », a small natural valley with an almost flat topology that divides the city of Mahajanga into two parts.

Regarding epidemics, the informal suburbs of the Mahajanga city have been hit by such diseases, including plague and cholera, which are linked to sanitation problems, precariousness and poverty (Migliani et al., 2000). This is the case of the Metzinger valley,

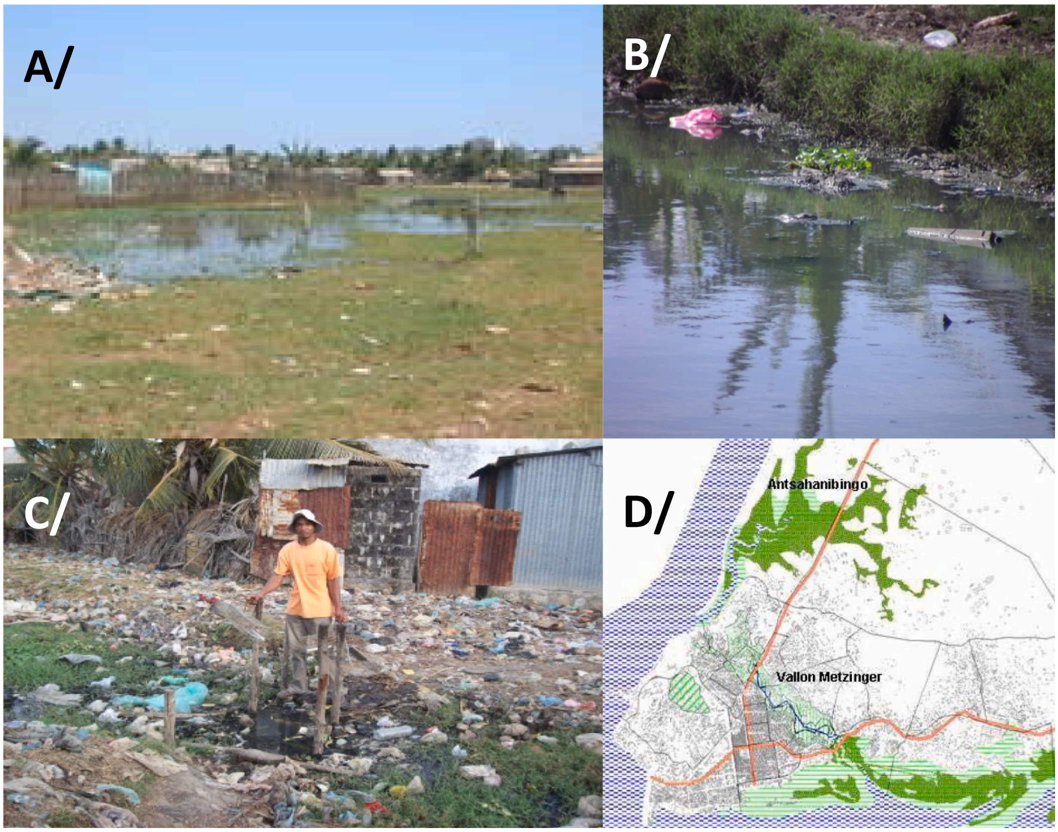

Fig. 1. A-B-C) views of the suburbs around the Metzinger channel. D) Map of Mahajunga with in blue the channel.

established at the beginning of the previous century and constantly subject to tides and more or less significant flooding episodes during each rainy season. The water level can then rise sharply, transforming the area into a lake. The urban area has undergone intense urbanization in the past decades, due to the demographic pressure, the proximity to the city center and low land costs. Becoming rapidly overcrowded, the insalubrity of these neighborhoods has been highlighted by epidemic events and has interest many public health actors. Yet, the political instability of Madagascar is challenging as the municipalities depend mainly on overseas partners for any development project. Indeed, with the financial support of the European Union, the Regional Institute for Cooperation

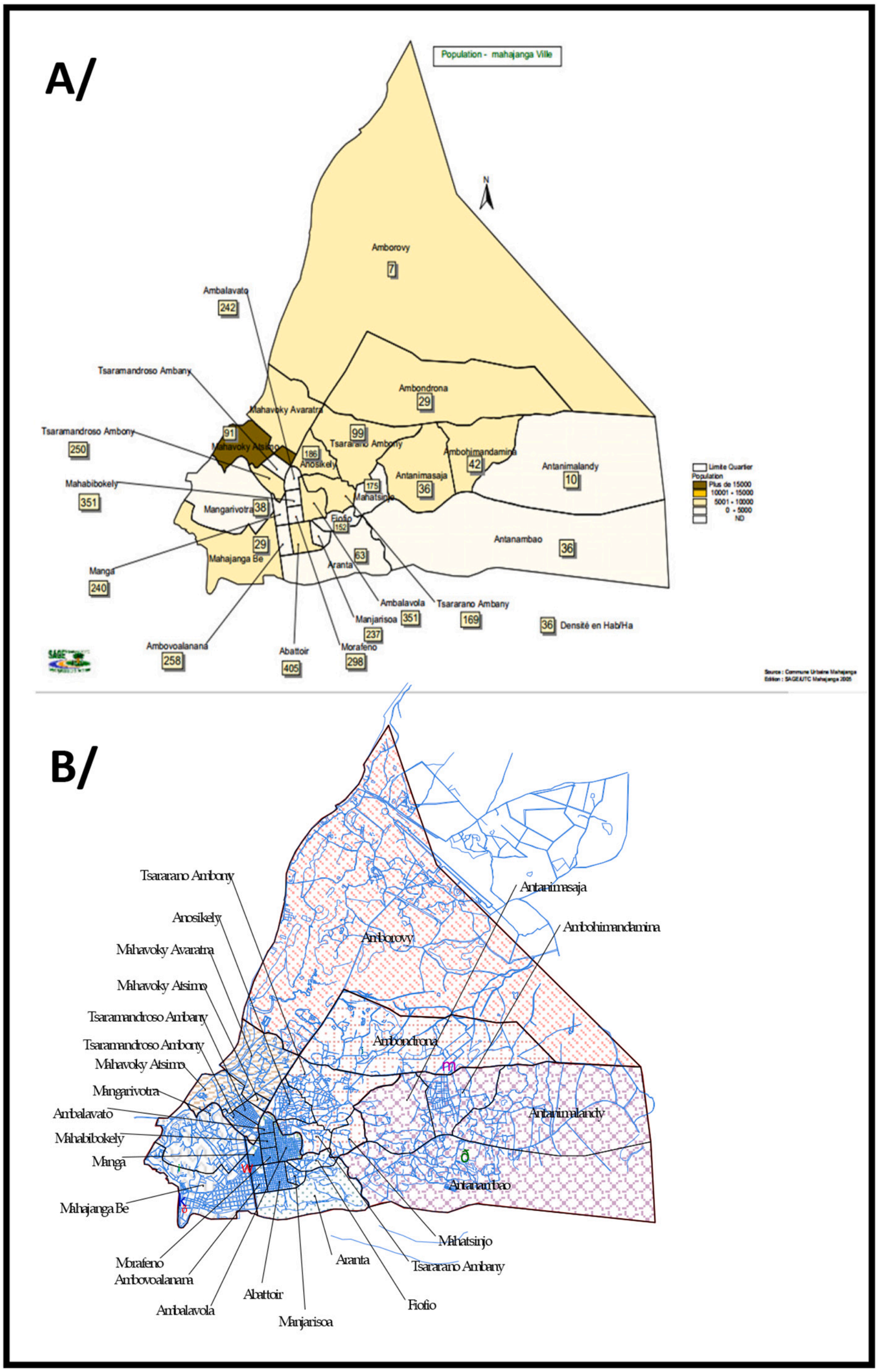

Fig. 2. (A) Map of the suburbs of Mahajunga. (B) Map of the water collection network of the town and the name of the suburbs

and Development (IRCOD) is launching the so-called project ASSMA - IRCOD that aims to structure the sanitary services in the city. This framework is scheduled for a period of four years and aims to improve access to sanitation for the inhabitants of the poor and vulnerable neighborhoods of Valley Metzinger and its surroundings. It includes the installation of latrines, the cleaning of canals and the organization of a waste collection service.

The objective of this study was to do a pre-intervention baseline evaluation of parasites contamination of the population. It will serve as a reference for fecal peril contamination of the environment. The second objective was to analyze the relationship between the socioeconomic situation of households and the presence of parasites in the fecal samples from children aged between 1 and 10 years. Others variables related to the house, the lifestyle and the household income have also been included for more comprehensive information.

2. Patients, materials and methods

2.1. Study site

The study was conducted in Mahajanga the main town of the north-western province of Madagascar. The city is divided in two parts by a small valley named “Metzinger valley”. During the colonial period, a large canal was built by Metzinger to collect surface water. Afterwards, this area was invaded by informal housing which disrupted drainage, resulting in frequent flooding in the area during rainy season, creating an unhealthy lake that persists for weeks (Fig. 1). The town of Mahajanga is divided into 26 neighborhoods out of which ten are located in the Metzinger valley (Fig. 2). In addition to four neighborhoods outside this area the Metzinger valley hosts 110,000 registered inhabitants with a density of >40,000 inhab/km2.

2.2. The sampling strategy

The target population of this study was the children under 10 years of age living in the 14 neighborhoods previously selected. The sampling of the households was based on the list of families registered at the civil-status department. Despite the low level of organization inthe area, each household was registered with a number on the administrative list. This number was also written on the door of eachhouse, thus allowing its localization in the quarter. The number of people per family was also registered on the same list. The objective was to randomly sample at least 50 children in each neighborhood. For each quarter, thirty families were randomly drawn from the list using the cumulative total household population to take family size into account. The enrolment of each family was preceded by the writing of an informed consent of the parents or tutors of the children. In each household, a questionnaire was submitted to the head of the household during a 30-min interview. Variables documented are listed in Table 1. In each registered family, all children under 10 years of age were included in the study. Exclusion criteria were the refusal of the legal tutor or an insufficient stool collection.

2.3. The data and samples collected

The variables investigated during the study as reported in Table 1 include information about the child (age, gender, weight, height, arm circumference, clinical symptoms) (UNICEF, 2021; WHO, 2006), the structure of the house and its environment (e.g., roof, walls, kitchen); the access to water and sanitation; the structure of the family; the education level of the parents and their profession. The consent to participate was obtained during a first interview with the legal representative of the family and the whole family in which the topic of the study was explained. After registration and collection of information, each child received an appointment for the next day for stool and blood collection (5 mL).

Table 1
Variables investigated during the study.

Variables selected for the model	Type de variable
Variables selected for the model	Type de variable
Gender	boolean / male reference (OD = 1)
Age	quantitative discrete
Class of age	discrete
Educational level of the mother	boolean / “no education” reference (OD = 1)
primary	boolean / “no education” reference (OD = 1)
secondary	boolean / “no education” reference (OD = 1)
high school	boolean / “no education” reference (OD = 1)
Quarter (Fokontany)	boolean / “Manga” reference (OD = 1) or “other”
weekly budget for food	quantitative continuous (logarythl)
Latrine in the household	boolean / “no latrine” reference (OD = 1)
Nbr of Inhabitants per room	quantitative continuous
Weekly nbr of meals with meat	quantitative continuous
poorness	boolean / “lower quintile of reachness” reference (OD = 1)
Treatment of water	boolean / “no treatment” reference (OD = 1)

2.4. Biological analysis

The stools collected were stored in a dichromate buffer before processing. A microscopy-based approach was performed with two steps. A direct examination of wet mount of fresh stools was conducted during the field study at the university hospital of Mahajanga. Wet mount readings were also operated after the Bailenger's concentration method (Bailenger et al., 1962). Bailenger's concentration pellet was spread on several smears, dried and fixed with methanol 10 min for specific stainings. The presence of coccidians (*Cryptosporidium*, *Isospora belli*, *Cyclospora cayetanensis*) was investigated using modified acid-fast staining (Chawla and Ichhpujani, 2011). *Cryptosporidium* positivity was confirmed by direct immunofluorescence (MeriFluor® Crypto/Giardia kit, Meridian Bioscience Inc., Italy) following the instructions from the manufacturer. Microsporidias were identified using modified trichrome staining and the T Van Gool's Uvitex 2B fluorescent staining protocol (Weber et al., 1994; Van Gool et al., 1993). The presence of *C. cayetanensis* was confirmed by autofluorescence using UV light (Bouree et al., 2007).

Table 2
Description of the population studied (variable distribution with the number of persons or household presenting each parameter).

Family description	Modalities	Number (%)	Household description	Modalities	Number (%)
	No education	182 (24.4%)		standpipe	549 (73.6%)
	Primary	4 (0.54%)		tap	182 (24.4%)
Educational level (Mother)	Secondary	466 (62.4%)		bottle	5 (0.67%)
	High school	53 (7.1%)	Source of water	tap + bottle	2 (0.27%)
	missing data	41 (5.5%)		well	3 (0.4%)
	Artisan	27 (3.6%)		standpipe + bottle	4 (0.54%)
	merchant	97 (13%)		missing data	1 (0.13%)
	farmer	12 (1.6%)		boiling	1 (0.13%)
	at home	385 (51.6%)		nothing	505 (67.69%)
	teacher	14 (1.9%)	Treatment of water	don't know	2 (0.27%)
Mother employment	hotel	26 (3.5%)		some time	116 (15.55%)
	student	2 (0.27%)		often	120 (16.1%)
	trader	16 (2.14%)		missing data	2 (0.27%)
	employee	18 (2.4%)			
	retired	1 (0.13%)		wood	46 (6.17%)
	nurse	3 (0.4%)		wood + coal	13 (1.74%)
	missing data	10 (1.34%)		coal	660 (88.47%)
	Artisan	152 (20.38%)	Type of heater	coal + Gaz	13 (1.74%)
	merchant	92 (12.33%)		electricity	5 (0.67%)
	grower	18 (2.4%)		electricity + coal	1 (0.13%)
	teacher	9 (1.2%)		gas	6 (0.8%)
	pupil	6 (0.8%)		missing data	2 (0.27%)
Father employment	hotel	12 (1.6%)		candle	32 (4.3%)
	trader	139 (18.6%)		electricity	611 (81.9%)
	fisherman	72 (9.65%)	Type of lighting	electricity and petrol	3 (0.4%)
	retired	10 (1.34%)		petrol	96 (12.9%)
	employee	89 (11.9%)		missing data	4 (0.54%)
	nurse	3 (0.4%)		concrete	89 (11.9%)
	missing data	139 (18.6%)		concrete + metal sheet	4 (0.53%)
	Yes	549 (73.59%)		wood	55 (7.37%)
Owning a TV	No	194 (26.01%)		wood + metal sheet	3 (0.4%)
	missing data	3 (0.4%)		cob	12 (1.6%)
	Yes	448 (60%)	Type of walls	brick	1 (0.13%)
Owning a radio	No	293 (39.28%)		concrete + brick	42 (5.6%)
	missing data	5 (0.67%)		brick + metal sheet	5 (0.67%)
	Yes	627 (84%)		stone	8 (1.07%)
Owning a cell phone	No	117 (15.68%)		metal sheet	526 (70.5%)
	missing data	2 (0.27%)		missing data	1 (0.13%)
	Yes	104 (13.9%)		wood	21 (2.82%)
Owning a fridge	No	621 (83.24%)		tilling	9 (1.2%)
	missing data	21 (2.8%)	Type of floor	Cement	653 (87.5%)
	Yes	33 (4.4%)		bare ground	62 (8.3%)
Owning a car	No	710 (95.17%)		missing data	1 (0.13%)
	missing data	3 (0.4%)		concrete	3 (0.4%)
	Yes	146 (19.57%)		wood	3 (0.42%)
Owning a bicycle	No	597 (80%)		straw	75 (6.03%)
	missing data	3 (0.4%)	Type of roof	straw + metal sheet	3 (0.40%)
	Yes	83 (11.13%)		metal sheet	652 (87%)
Owning a moto	No	661 (88.6%)		tiles	9 (87.4%)
	missing data	2 (0.27%)		missing data	1 (0.13%)
	Yes	675 (90.5%)		Yes	618 (82.8%)
inhouse shower	No	68 (9.12%)	Inhouse sanitation	No	125 (16.7%)
	missing data	3 (0.4%)		missing data	3 (0.4%)

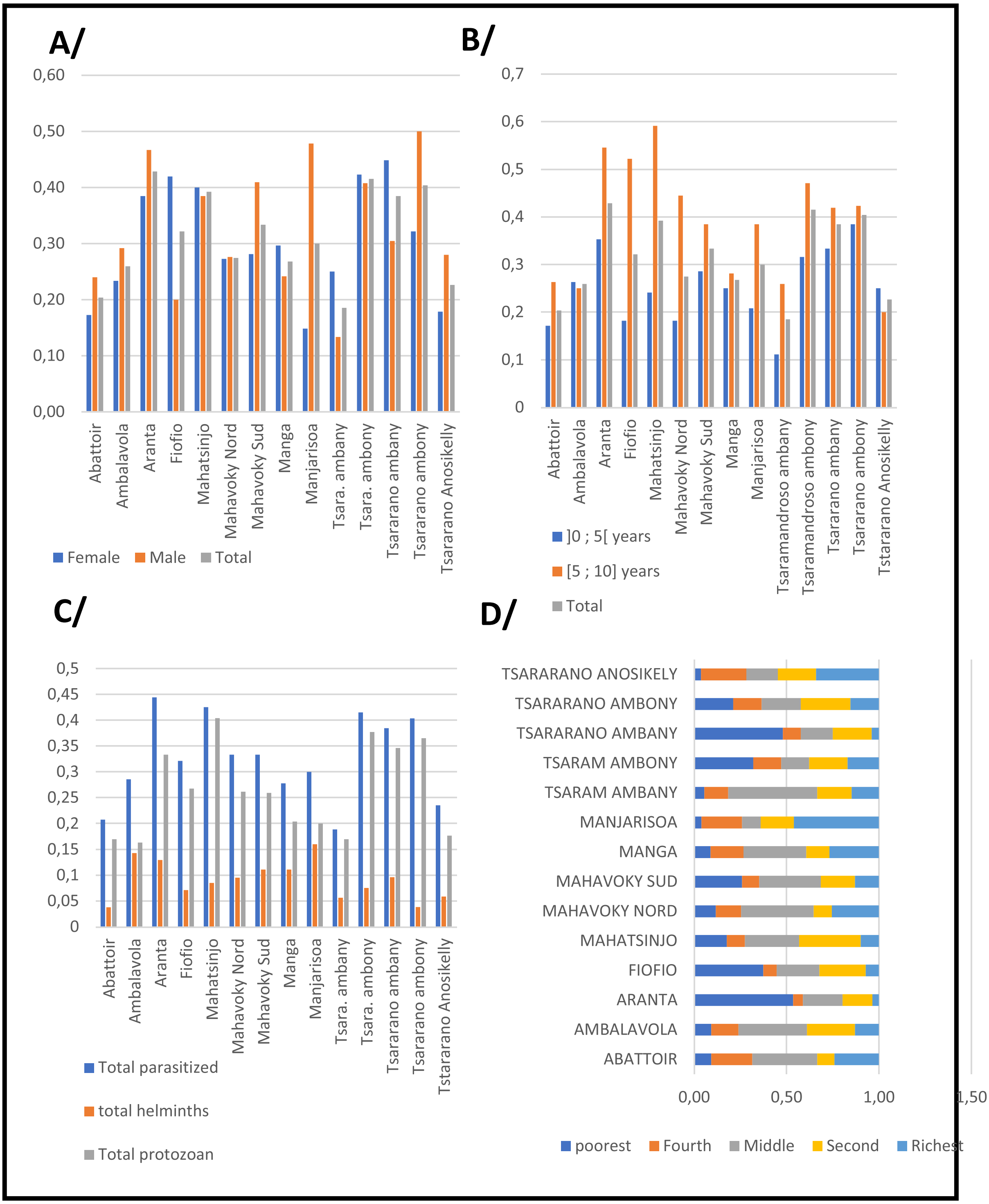

Fig. 3. A) parasite carriage (frequency) in the different suburbs of the town, according to the gender of the child. B) parasite carriage (frequency) in the different suburbs of the town, according to the age of the child. C) helminths and protozoan carriage (frequency) in the different suburbs of the town. D) quintile richness repartition of the households in the different suburbs.

2.5. Statistical analysis

For the logistic regression analysis, quantitative variables (e.g., famly income) were divided into classes using the quintile distribution of the value registered on the entire population. Logistic regression was conducted using the « Backward » regression method with variables preselected during mono-variate analysis. A *P*-value of 0.2 was used for this selection.

To address the question of the role of wellbeing in the contamination by parasites, a global score was established by integrating indicators such as sanitation, the possession of a radio or a car etc. Instead of defining an absolute score, it was decided to analyze data according to the population quintile. The strategy was to summarize data through a multicomponent analysis (MCA) of the variables and to look at the repartition of the inhabitants according to their coordinates on the first axis of the MCA. Quintile of persons were constituted. The variables used for the MCA werethe indicators describing the quality of the house (type of roof, floor, walls and lighting, shower, latrines) and the variables in relation with household goods (TV, Radio, cell phone, fridge, car, moto bike, bicycle). For some variables, recoding was needed. The quintile of wellbeing was then a sign of lack of goods. People classified in the first and second quintile were considered as the poorest of the population.

3. Results

3.1. The population enrolled

The study was conducted over aone -month period and 746 children were registered. The number of children recruited varied slightly between places. The description of the population is summarized in Table 2. The average number of persons per household was 5.52 (SD 2.2). No clear difference in age or gender balance was observed from one quarter to another. The population was young in accordance with the whole population of Madagascar, and only 22.9% of the families didn't have children under 5 years of age. The average numbers of children under 10 years of age and under 5 years of age were 2.8 (SD 1.5) and 1.7 (SD 0.8) respectively. The mothers were young (mean 32, SD 8.46), and their educational level was also low with 24.4% of the mothers without any education and 62.4% having reach the secondary level. Among the mothers, 51.6% worked at home but 13% also had a commercial activity. Men were mostly artisans (20.4%) or traders (18.6%).

Most of the houses were built with metal sheets (87.5%) and 73.6% of families use communal standpipe for water supply (67.7% do not treat water before consumption). Showering and sanitation were quite frequent in backyards with only 9.1% and 16.7% of the families not having these facilities respectively. >80% of the families did not have any transportation facilities (car, bicycle, motobike). However >60% of the households had some electronic devices (TV, radio, cellphone). The weekly food budget for the whole family was 3 euros (SD 1.5 euros). However, people also declared having some meat on average 4.6 times a week (SD 3.5).

The level of poverty of the participants was difficult to access through international criteria. Data were used to build a local relative score based on quintile of the whole population instead of international criteria. A multicomponent score of poverty was built. During MCA, the variance expressed by the first axis was 71% which strongly support this strategy.

(cf supplementary data for details and most represented variables). The repartition of the different quintile of population in the different quarters was not homogenous (Fig. 3D). Some quarters like Aranta, Tsararano Ambony hosted the poorest populations of the area.

3.2. Intestinal parasite prevalence

After methiolate, giardia was the most prevalent protozoan found with 10,1% of positivity among children under 5 years of age and 9,5% among those between 5 and 10 years old. Not significant difference of prevalence was found between girls and boys (8.5% and 11.1% respectively), and no difference was observed according to the class of age. However, some differences existed between quarters. The prevalences of *Entamoeba hartmani* and *Spiralis* was lower than that of *E. coli* with 1.4%, 0.4% and 16.7% respectively. No difference could be found between genders for *E. coli* but a significant difference was observed according to the age (9;1%) for those under 5 years of age and 22.6% for those older than 5 years old ($p < 0.01$). No significant difference could be observed according to age and gender for *E. hartmani* and *Spiralis*. For helminths, the prevalence of *Trichuris*, *Ascaris*, *Hymenolepis nana* and *Schistosoma mansoni* was 5.4%, 1.8%, 0.4% and 0.2% respectively. No gender difference was observed, but *Trichuris* was more prevalent in children older than 5 years old (7.0% and 3.5% respectively).

3.3. The socio-economic context and parasite prevalence

The educational level of mothers had a major impact on the prevalence of parasites in children. The frequency of infection decreased when the educational level increased. Indeed, for giardia, the prevalence decreased from 23,5% which corresponded to mothers without education, to 8% which corresponded to mothers with higher education. This was globally true for all the protozoans found. The prevalence of *E. coli and E. hartmani* decreased from 20.6% which corresponded to mothers without education to 2.9% which corresponded to mothers with higher education. The same was observed for helminths like *Trichuris*, *ascaris* and *S. mansoni*, but not for *H. nana* and *Spiralis*.

In the same line, the global level of poverty of the family as defined with MCA, was linked with the prevalence of parasites. The prevalence of *Giardia* was higher for poor households (quintile very poor and poor) than in those with the highest quintile of richness (delta 6,5%, $p < 0.01$). This difference was not detected for *E. hartmani* and *Spiralis* but was significant for *E. coli* (19,7% versus 14,6%,

$p < 0.05$). For helminths, the only difference was found for A*scaris* (2.6% versus 0.7%, $p < 0.05$).

3.4. The geographic distribution of parasites

A variation in the prevalence of parasites was detected according to the quarter (fokontany) raising from 19% to 41.5% for children with parasitic infection (Table 3, Fig. 3A-B-C). Indeed, *Giardia* was more prevalent in Tsararano AmbanyTsaramondroso and less prevalent in Manga with 19.2%, 17% and 3.7% respectively. A gender difference in prevalence was also found according to the neighgborhood, with more males infected by *Giardia* in Manjarisoa andTsaramandroso Ambany. *E. coli* was more prevalent in Tsararano Ambony (32.7%) and inMahatsinjo (25.5%) and less prevalent in Ambalavola(4.2%). Two fokontany were specifically concerned by *Trichuris,* Mahavoky Sud and Aranta with a prevalence of 11.1% and 9.3% respectively. Half of the fokontany were infected by ascaridiosis with the highest prevalence observed in Ambalavola (6,3%). *H. nana* was found in three quarters Aranta, Tsararano Ambony and Tsararano Anosikely. *S. mansoni* was only found in one fokontany (Manjarisoa 7.7%). This spatial repartition supportedthe existence of specific factors sustaining transmission in these quarters.

3.5. Multivariate analysis of risk factors for parasite carriage

Logistic regression was used to conduct a multivariate analysis. Among protozoans, only *Giardia* was prevalent enough to conduct such a risk factor analysis. For helminths, a risk factor analysis was conducted for all the contaminations (all helminths together) and for *Trichuris* specifically. Risk factors were also searched for polyparasitism (helminth + protozoans) (Table 3).

3.5.1. Risk factors for Giardia contamination

The model was significant ($p < 0.01$) with a pseudo R^2 at 4.3%. The size of the household was not retained as risk factor but the level of richness had a major impact as poorest families had a 3 times higher risk of infection ($p < 0.05$). The age of the child was also important with a risk of infection doubling each year for youngest children, then decreasing again for older ones. No impact of the quarter was retained.

3.5.2. Risk factors for helminths contamination

This contamination takes into account the presence of *Spiralis* or *Trichuris* or *H. nana* of *S. mansoni* (the prevalence of the other parasites being too low for the analysis). The model was also significant with $p < 0.01$ with a pseudo R^2 at 4.3%. The age of the child (considered as the square of age in year) was a risk factor for contamination. The low education level of the mother was also predictive of contamination especially for mothers without education. Contamination by Trichuris by itself was also predicted from the age of the child and from the education level of the mother (model significant with $p < 0.01$ with a pseudo R^2 at 6.2%).

Table 3
Logistic regression analysis of the risk (OD) of parasite carriage associated with each factor.

	Odds Ratio	Std. Err.	z	P-value	[95% Conf.	Interval]
Giardia						
Habperpiece	1.0732	0.0568	1.34	0.182	0.9675	1.1906
Age	1.9009	0.4849	2.52	**0.012**	***1.1530***	***3.1338***
class of age	0.9423	0.0218	−2.56	**0.010**	0.9004	0.9861
poorness	1.9739	0.5249	2.56	**0.011**	***1.1722***	***3.3240***
quarter other than “Manga”	2.7147	2.0052	1.35	0.176	0.6382	11.5468
Constant	0.0049	0.0050	−5.21	**0.000**	0.0007	0.0361
Helminths						
quarter other than “Manga”	0.5268	0.2507	−1.35	0.178	0.2072	1.3391
class of age	1.0135	0.0047	2.91	**0.004**	***1.0044***	***1.0227***
primary	0.4198	0.2090	−1.74	0.081	0.1582	1.1138
secondary	0.2547	0.1202	−2.90	**0.004**	0.1010	0.6423
high school	0.2682	0.1963	−1.80	0.072	0.0639	1.1261
Constante	0.2466	0.1585	−2.18	**0.029**	0.0700	0.8688
Trichomonas						
food budget	0.6795	0.1910	−1.37	0.169	0.3917	1.1787
quarter other than “Manga”	0.3977	0.2119	−1.73	0.084	0.1399	1.1303
class of age	1.0176	0.0054	3.27	**0.001**	1.0070	1.0282
primary	0.4325	0.2500	−1.45	0.147	0.1393	1.3429
secondary	0.2842	0.1571	−2.28	**0.023**	0.0962	0.8395
high school	0.2826	0.2495	−1.43	0.152	0.0501	1.5951
Constant	4.8240	12.1528	0.62	0.532	0.0346	672.6576
Multi-parasites						
secondary	0.5618	0.1699	−1.91	0.057	0.3105	1.0163
water treatment	0.5825	0.2162	−1.46	0.145	0.2814	1.2056
class of age	1.0136	0.0048	2.82	**0.005**	1.0041	1.0231
poorness	2.1871	0.6763	2.53	**0.011**	***1.1931***	***4.0094***
Constant	0.0453	0.0172	−8.14	**0.000**	0.0215	0.0954

3.5.3. Polyparasitism

Polyparasitism was considered as the presence of at least two different species of parasites. The model was also significant with $p < 0.01$ with a pseudo R^2 at 5.8%. Age was again a major factor with the risk increasing with the number of years. The poorest families had a risk twice higher than the others. The risk also increased for children with mother without education. The treatment of water was negatively associated with the risk of contamination (but not significant).

4. Discussion

In the studied area, t, intestinal parasitosis was the leading cause of morbidity among children between 1 and 10 years of age due to the lack of knowledge about hygiene among the population and the exposure to an unhealthy environment. The aim of this study was firstly to identify the intestinal parasites present in the faeces of children aged between 1 and 10 years, then to analyze the relationship between the presence of the parasites and the socioeconomic status of the households in order to determine the risk factors for intestinal parasitosis In nine quarters, >30% of the children were parasitized. Therefore, this study was important to identifying high-risk fokontany that should be the target some additional priority interventions.

Microscopic examination identified highly predominant species of intestinal parasites like *Giardia*, *Trichocéphale*, *Ascaris*, *H. nana*, *S. mansoni*, *E. coli*, *E. hartmani*, and *Anguillule*. These intestinal infections were widespread over the 14 fokontany by the valley. Tsararano ambany and Tsararano ambony were the most affected by parasites such as *Giardia*, *Ascaris* and *E. coli* with an overall frequency of 35%. This prevalence is common in intertropical towns like in the city of Itabuna, Bahia (31.2%), in Ivory Coast (55.2%) (Mariano et al., 2015; Adoubryn et al., 2012) or even in the Sahelian region like in Niamey in Niger (33%) (Soumana et al., 2016). This high prevalence of intestinal parasitosis is similar to those observed in villages in Burkina Faso located near the rivers and in flood zones (Dianou et al., 2004).

Giardia intestinalis was the most frequently encountered parasite with a prevalence of 19.2%. This prevalence is low compared to what was found by other studies (Soumana et al., 2016). The highest prevalence of *Giardia* was found in the Fokontany "Tsararano Ambany", a frequently flooded area near the canal with a rate of 19.2%. This prevalence of *Giardia* decreased when the mother's level of education was high. This was already pointed out by other authors (Kanga, 2009; Gnogbodji, 2008; Develoux and Alarou, 2010). i.e., the more educated the parents, the less parasitized the children. This relation was not found in Ivory Coast (Ouattara, 2009; Ble, 2010). The prevalence of *Giardia* parasite was also higher in the very poor and poor quintiles of households. Taken together, these two parameters are sufficient to explain prevalence and the living space was not significantly linked to the prevalence. This supports the idea that the local environment of the family is more important than the quarter itself, which paves the way to educational programs.

Concerning non-pathogenic protozoa like *E. coli*, the highest prevalence was 32.7%, with no significant difference according to gender, but children over 5 years of age were the most affected. This group represents the school age where the risk of contamination is high. The prevalence of *E. coli* also differed between poor and poorest households. Tsararano Ambony was the most affected fokontany with a prevalence of 32.7%. These results are in line with other studies carried out by Kouassi et al., 2019 in Ivory Coast or Bervas in Guadeloupe (Kouassi et al., 2019). Giardia and *E. coli* are good markers of fecal contamination of the environment which correlated with poor sanitary practices, consumption of contaminated water and food (Greigert et al., 2018; Chelkeba et al., 2020). Although this parasite is not pathogenic, it is a very good indicator of the level of hygiene and insalubrity as already reported in other countries (Kouassi et al., 2019).

Pathogenic helminths were represented in decreasing order, by whipworm, *Ascaris*, *Hymenolepis nana* and *S. mansoni*. *Trichocephalus* is a cosmopolitan parasitosis, more common in hot and humid climates. It is on the WHO list of neglected tropical diseases. In tropical countries, particularly in poor rural areas with fecal peril, the infestation can be massive and serious, especially in children. Concomitant infections with other worm-like organisms, such as *Ascaris lumbricoides*, can cause premature stunting, mental retardation and cognitive abnormalities (Bethony et al., 2006). Intestinal helminthic infections can aggravate problems related to micronutrient deficiency.

Overall, the level of education of the parents and the quintiles of standard of living were the main factors linked to the presence of parasites. The establishment of a sanitation chain, the use of latrines and the application of hygiene measures were thus essential The living space (and thus the Metzinger valley) was not a predominant risk factor. Mass de-worming programs, sanitation improvement and monitoring of latrines must be urgently implemented, with the target being the most infected children i.e., those at school age. Awareness-raising activitiestargeting the parents is needed, including awareness on fecal hygiene, proper maintenance of toilets and appropriate treatment of water (Halliday et al., 2019). It would be important to share these data with public health officers to develop educational programs to reduce the incidence of infections and illness in children living in this endemic area (WHO, 2006). Moreover, few studies have been done on the epidemiological profile of intestinal parasitosis in Mahajanga including the Metzinger valley, thus, this study provides a database for surveillance and prevention of fecal-related infectious diseases and for future sanitation projects.

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Ethical approval

This project was approved by the National Ethic Committee of Madagascar.

Declaration of Competing Interest

No conflict of interest was declared.

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