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RETROSPECTIVE STUDY OF MALARIA PREVALENCE AND *Anopheles* GENUS IN THE AREA OF INFLUENCE OF THE BINATIONAL ITAIPU RESERVOIR

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SUMMARY

The importance of hydroelectric dams beside the human interchange in the maintenance of malarious foci and the occurrence of the *Anopheles* genus on the Binational Itaipu Reservoir were the main points of this retrospective study. Data were collected from existing registrations at National, State and Municipal Health Departments and literature systematic overview, from January 1984 to December 2003. The occurrence of some outbreak of malaria, mainly by *Plasmodium vivax*, and the prevalence of species of the *Anopheles* genus different from *Anopheles darlingi* in the region are discussed. The malaria in the left bank of Paraná River is a focal problem, which must be approached locally through health, educational and social actions to prevent the continuity of outbreaks in the area. Concomitantly, it is necessary to plan and apply effective surveillance measures in the influence area of the Itaipu Reservoir.

KEYWORDS: Malaria; *Anopheles*; *Plasmodium vivax*; Binational Itaipu Reservoir.

INTRODUCTION

In Brazil, annual cases of malaria have fluctuated around 500 thousand since 1990¹⁹. The Legal Amazon Region is responsible for 99% of those cases¹⁴. For the other regions and states, recorded cases are nearly always imported from the Amazon region or from other countries where vectorial transmission is occurring¹⁴. Paraná, São Paulo and Mato Grosso do Sul are states that receive greater number of cases “exported” from the northern region of the country². The migrations between the west of Paraná and the Brazilian Amazon and the pendular movements of the population between the west of Paraná and Paraguay facilitate the continual reintroduction of the etiologic agent and the occurrence of autochthonous cases of malaria in the area of influence of the Itaipu Reservoir⁸.

Before the beginning of the construction of the Hydroelectric of Itaipu the flow of people between the west of Paraná and the Paraguay territory was moderate, with focus on the activities of tourism and business. With the shutting of the Itaipu Dam in October 1982, Sete Quedas Falls disappeared, facilitating the interchange of people⁸. After that the frequency of migration between the two countries, Brazil and Paraguay, risen. Mainly needy people of low income as well as an input of dam workers were coming from other parts of Brazil⁶. We also have to consider that from the 70s, with the colonization of Legal Amazon, there was an intense migratory exodus of the population of Paraná, among them ex-land owners and rural employees from

expropriated land for the construction of Itaipu Reservoir, towards the northern and center-western regions of Brazil¹.

Regarding the *Anopheles* (*Nyssorhynchus*) *darlingi*, the main vector of malaria in Brazil, after the malaria outbreak occurred in 1950 in the area from the Paranapanema River to the mouth of the Paraná River, the species was found in all of the riverine locations investigated¹⁵. After the interruption of the transmission of the malaria between the 1960s and 70s, Paraná State was considered an area of low malaria risk. In 1974, the “Superintendência de Campanhas de Saúde Pública – SUCAM” (a State Department to control endemic diseases) – elaborated a program of preventive activities for reducing the reintroduction risk of malaria in Guaíra, Marechal Cândido Rondon, Santa Helena, São Miguel do Iguçu and Foz do Iguçu, which are municipalities located in the western region of the state under influence of the Itaipu Reservoir (Fig. 1), corresponding to 7,000 km³. Nowadays, despite the stability of the biggest part of the population, the existence of infra-structure of housing and the predominance of secondary species of *Anopheles*, this area conserves the malarious potential which brings around sporadic transmission in restricted areas¹⁸.

The aim of this work was to carry out a retrospective study of human malaria cases and the occurrence of *Anopheles* genus mosquitoes on the impact area of the Binational Itaipu Reservoir, left margin of the Paraná River.

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MATERIAL AND METHODS

Study area: The studied municipalities are located in Western region of Paraná State, area of influence of the Itaipu Reservoir, in the left bank of the Medium Paraná River (Fig. 1). Being part of the third plateau of the Paraná State, the study area belongs to the geomorphologic unit of the central plateau of the Paraná Basin (CD Weather Maps of Paraná). The reservoir comprises the municipalities from Guaíra to Foz do Iguaçu, occupying an area of 180 km². Foz do Iguaçu, the most populous municipality, has 251,000 inhabitants. The region presents declivity on the east to west direction with average quotas from 100 to 300 m. The towns of Foz do Iguaçu, Santa Helena, Santa Terezinha do Itaipu and Guairá, present the altitude of 164, 258, 218 and 220 m, respectively. In the Indian Settlement of Ocoi, São Miguel do Iguaçu town, in the vicinity of Itaipu Reservoir margin, the average altitude is 113m.

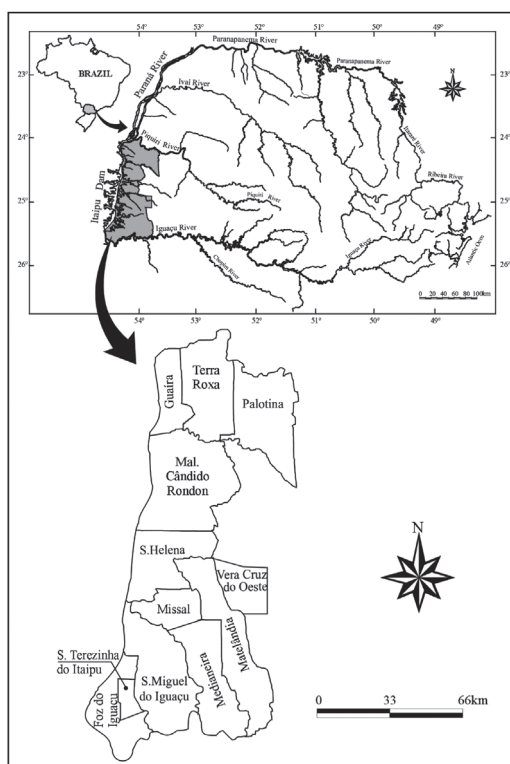


Fig. 1 - Location of the municipalities in the left bank of the Medium Paraná River and of the Itaipu Binational Reservoir Hydroelectric Dam.

The areas now occupied by the Itaipu Reservoir were covered by primitive forests in 1960. The dam is located 16 km upstream of the Iguaçu River. Closed in October 1982, it has reached the normal quota of operation in 1984. After the damming, the level of the water was elevated from 100 to 220 m above the sea level⁸.

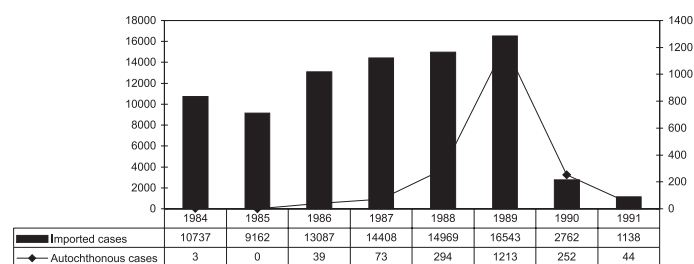
Study outline: This work was based on a retrospective study of human malaria cases and of the occurrence of *Anopheles* genus mosquitoes on the left margin of the Paraná River, impacted area of the Binational Itaipu Reservoir, after the formation of the reservoir. The study period was from January 1984 to December 2003.

Data collection: Data of malaria were collected from existing registrations at National Health Foundation (FUNASA) of Paraná, Municipal Health Departments, Paraná State Health Department and literature.

Data of the *Anopheles* genus utilized came from a literature systematic overview.

RESULTS

From the shutting of the dam until 1985, human malaria autochthonous cases in the medium Paraná River were nearly non-existent, but the number of imported cases was around 10,000/year. Since then, the registrations show an increase of autochthonous human malaria cases in the region, reaching 1,213 autochthonous cases and 16,543 imported cases in 1989 (Fig. 2).



Source: FUNASA/Itaipu Binational Medical Entomology Laboratory

Fig. 2 - Autochthonous and imported cases of malaria diagnosed in western Paraná, area of influence of the Itaipu Reservoir, from 1984 to 1991.

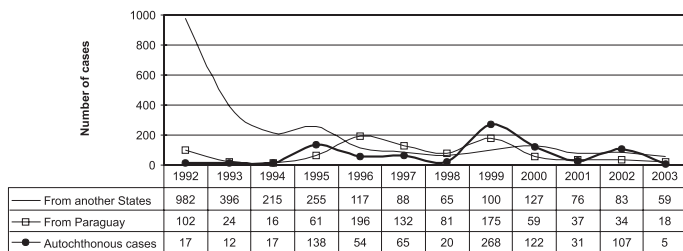
The autochthonous cases of malaria registered in that region in 1986 were 29 in Foz do Iguaçu, nine in São Miguel do Iguaçu and one in Santa Helena⁸. In 1988, 83% of them occurred in the municipalities of Foz do Iguaçu, Santa Terezinha do Itaipu and São Miguel do Iguaçu. Starting on February 1989, the epidemic outbreak of malaria emerged mainly in Foz do Iguaçu and São Miguel do Iguaçu, involving 706 and 205 annual cases¹³, respectively, with 97.4% of *Plasmodium vixax* and 2.6% of *Plasmodium falciparum*⁸.

From 1984 up to 1988 the months of greatest number of malaria cases were March and May^{5,8}. In 1989, it happened mainly in the months of March, April and November, although autochthonous cases of malaria occurred throughout the year⁸.

In 1990, 252 autochthonous cases of malaria were still registered in the area of influence of Itaipu (Fig. 2). From these, 192 (76.2%) occurred between January and May, and the municipalities mostly involved were Foz do Iguaçu, Santa Helena, Guaíra, and São Miguel do Iguaçu. The municipality of Guaíra, that had presented four cases in 1989, registered 39 in 1990, seven of which were caused by *Plasmodium falciparum*⁸. The reduction of the malaria cases in the region occurred at the same time that the diseased people were treated through FUNASA – National Health Foundation – (FUNASA, 2001) following therapeutic programmes recommended by the Health Department (Bilio). From 1989 to 1994, the combat to the vector was accomplished by semi-annual sprinkling of every house located as far

as 5,000 m from the margin of Itaipu lake, reaching the urban areas of Foz do Iguacu, Santa Terezinha do Itaipu, Santa Helena and Guaíra.

In 1995, 1999, 2000 and 2002 the number of autochthonous cases rose to more than one hundred (Fig. 3) equating with the adding up of imported cases from other states and Paraguay. In 1995 the autochthonous cases happened mainly in Foz do Iguacu and Santa Terezinha do Itaipu while from 1996 to 1999, they were registered mostly in Foz do Iguacu and in the years 2000 to 2002, in São Miguel do Iguacu. From January 1997 to December 2002, all of the autochthonous cases diagnosed in the region were of *Plasmodium vivax*²¹.



Source: FUNASA/SESA/CSA/DCDTV

Fig. 3 - Autochthonous and imported cases origin of malaria diagnosed in western Paraná, area of Influence of the Itaipu Reservoir, from 1992 to December 2003.

The imported cases of malaria in the area of influence of Itaipu came as much from the other Brazilian states (Legal Amazon) as from Paraguay (Fig. 3). During the years from 1992 to 1995, 2001 and 2003 prevailed the number of imported cases from other states whereas from 1996 to 1998, most imported cases came from Paraguay (Fig. 3).

In relation to the species of *Anopheles* found in the region of influence of the Binational Itaipu Reservoir, the occurrence of *An. darlingi* was registered in almost the whole period investigated except between 1994 and 1997 in punctiform data collection^{10,11}. In general, this species have always presented a low prevalence in relation to the others, except in periods of outbreak, where the prevalence had been higher than 10%^{9,13} (Table 1). The predominant species in that region were *An. albitarsis*, *An. evansae*, *An. argyritarsis* and *An. galvaoi*. The species *An. albitarsis* and *An. galvaoi* were prevalent in collections realized near the Itaipu Reservoir including human baits¹⁷.

The autochthonous cases of malaria in the investigated area, in the period from 2000 to 2003, occurred mainly in the Indian Settlement of Ocoi, located in São Miguel do Iguacu and in inhabitants of Foz do Iguacu, Santa Helena and Santa Terezinha do Itaipu. In almost every age group, individuals of the masculine sex were the most attacked (Table 2). As for the occupation, excluding the indigenous population, 23 professional categories were found, and the most reported ones were farmer, housewife, mason and fishermen. Such data confirm that there was transmission in the reported period, as much in outdoors as in indoors, with no clear delimitation between the semi-rural and rural areas.

DISCUSSION

The area where the Itaipu reservoir is situated, the region of the

medium Paraná river, has passed through several phytogeographical and ecological changes. From 1968 to 1982 its waters normally had a great outgo, which flew through steep slopes of more than 100 m⁽⁴⁾. After the construction of the reservoir the waters became less turbulent facilitating the formation of marshes and backwaters, ideal for the installation of *Anopheles* breeding places⁵. Modification in the climate, especially as for the greater level of humidity, can have also influenced in the proliferation of the *Anopheles*⁸. These facts combined with the intense flow of incoming people from endemic areas, were responsible for the dozens of imported and autochthonous cases of malaria annually registered in the Itaipu area^{17,18}.

Before the construction of the reservoir there was sporadic registrations of malaria mainly in the period from February to June, subsequent to the great floods in the area between Guaíra and Foz do Iguacu⁴. However, in the Upper Paraná River, area between Guaíra and São Paulo state, the malaria occurred in epidemic outbreaks¹⁵. At this same area, the *Anopheles*' density, especially of *An. darlingi*, was higher than in the area of the Medium Paraná River⁴. With the shutting of the Itaipu dam and the maintenance of the breeding places for *An. darlingi* it was expected to have had an expressive number of cases of malaria especially in the Upper Paraná River⁵. The adoption of satisfactory preventive measures has supported the low incidence of malaria in that region following the normal pattern⁵. Whereas in the low part of the Medium Paraná River, where the density of *An. darlingi* began increasing only after 1983⁵, cases of autochthonous malaria were registered especially in the municipalities of Foz do Iguacu, Santa Terezinha do Itaipu and São Miguel do Iguacu¹⁶. In 1986 the autochthonous malaria was registered in Foz do Iguacu, firstly in urban population nuclei of medium and low income like those situated in the areas close to where the Itaipu Reservoir was built⁸. It is important to mention that this municipality is far from the region of Guaíra (Fig. 1) where the cases of malaria initially predominated. In the cold months, June and July, and the months of low relative humidity, August and September, there was interruption of the transmission due to the low density of the vector⁸.

From 1986 onwards, cases of autochthonous malaria in the area of Medium Paraná River began to rise, reaching a sharp point in 1989 (Fig. 2). This picture could be explained by the introduction of abundant infection sources of imported cases into the area (gametophorous)⁵, as well as the presence of *An. darlingi*⁵. As this species have not always been present in the area studied (Table 1), it also suggests the involvement of other species in the transmission of malaria as *An. albitarsis* and *An. galvaoi*^{10,20} that had showed especially attracted by human baits¹⁰. *An. evansae* and *An. darlingi* were collected through human baits inside home and *An. argyritarsis* outside home⁷. It is important to mention that secondary species like *An. albitarsis*, *An. aquasalis*, *An. cruzii* and *An. bellator*, have always predominated in malarious areas where *An. darlingi* could be also found¹². The outstanding presence of *An. albitarsis sensu lato* in collections carried out in the town of Guaíra, with human baits and Shannon trap, suggests its indication as a possible participant in the epidemiological chart of malaria in the region^{10,20}. The control of the outbreak in mid 1990 was due to the sprinkling insecticide carried out by FUNASA, done especially in the cold or dry months (May to September), besides the treatment of the infected individuals⁸.

Table 1
Anopheles species in the left bank of the Binational Itaipu Reservoir according to the literature, from 1978 to 2003

Investigation period	Region or Municipality	Species	Prevalence (%)	Total number of <i>Anopheles</i>	Type of collection
Jan/78 - Mar/85 ⁵	Foz do Iguaçu Terra Roxa Guaíra Mal. Cândido Rondon Santa Helena S. Miguel do Iguaçu	<i>An. darlingi</i>	–	Non mentioned	Human bait near the forest
Jan/89 - Dec/89 ¹³	Foz do Iguaçu Terra Roxa Guaíra Mal. Cândido Rondon Santa Helena S. Miguel do Iguaçu	<i>An. albitarsis</i> <i>An. evansae</i> <i>An. darlingi</i>	47.5 27.8 11.5	4,247	Human bait domicile and extradomicile
Jan/89 - Dec/89 ¹³	Foz do Iguaçu Terra Roxa Guaíra Mal. Cândido Rondon Santa Helena S. Miguel do Iguaçu	<i>An. evansae</i> <i>An. albitarsis</i> <i>An. darlingi</i>	48.4 33.3 2.6	2,500	Trap (immature stages) border of Paraná river
Jan/91 - Dec/91 ²⁰	Guaíra	<i>An. darlingi</i>	–	01	Human bait extradomicile-urban area
Nov/94 - Aug/95 ¹⁰	Guaíra	<i>An. albitarsis</i> <i>An. galvaoi</i> <i>An. evansae</i>	61.7 35.2 1.3	6,973	Human bait Shannon trap forest of Itaipu Reservoir
Jan/96 - Dec/97 ¹¹	Foz do Iguaçu	<i>An. albitarsis</i> <i>An. galvaoi</i> <i>An. mediopunctatus</i> <i>An. evansae</i> <i>An. lutzii</i> <i>An. fluminensis</i>	30.9 20.7 10.2 9.7 8.4 6.9	3,019	Human bait Shannon trap Iguaçu National Park
Aug/97 - Dec/97 ⁷	S. Terezinha do Iguaçu S. Miguel do Iguaçu Missal Santa Helena	<i>An. galvaoi</i> <i>An. evansae</i> <i>An. oswaldoi</i> <i>An. lutzii</i> <i>An. darlingi</i>	28.5 26.3 10.2 9.5 5.8	Non mentioned	Human bait Shannon trap domicile, extradomicile, Forest border - Iguaçu National Park
Oct/97 - Oct/99 ⁹	Guaíra to Foz do Iguaçu	<i>An. evansae</i> <i>An. argyritarsis</i> <i>An. darlingi</i> <i>An. lutzii</i> <i>An. strodei</i> <i>An. parvus</i> <i>An. galvaoi</i> <i>An. albitarsis</i>	21.9 15.7 15.4 10.0 9.8 9.6 8.0 4.6	8,408	Human bait Shannon trap domicile, peridomicile Forest border and interior Area of influence of Itaipu reservoir
Oct/97 - Nov/00 ¹⁷	São Miguel do Iguaçu	<i>An. evansae</i> <i>An. argyritarsis</i> <i>An. lutzii</i> <i>An. parvus</i> <i>An. strodei</i> <i>An. albitarsis</i> <i>An. galvaoi</i> <i>An. darlingi</i>	22.3 21.3 12.1 10.1 9.4 9.1 5.6 4.4	5,322	Human bait Shannon trap domicile, Forest border Indian settlement
Jan/00 - Dec/01 ¹⁶	São Miguel do Iguaçu	<i>An. argyritarsis</i> <i>An. albitarsis</i> <i>An. evansae</i> <i>An. lutzii</i> <i>An. parvus</i>	43.8 21.5 11.2 11.2 7.4	162	Human bait Shannon trap domicile, Forest border Indian settlement

Table 2

Distribution of autochthonous cases by age, sex and Indigenous population in the left bank of the Binational Itaipu Reservoir, from 2000 to 2003

Age (years)	Sex		Indigenous population		Total
	Male	Female	Number	%	
≤ 7	32	23	47	85.4	55
≥ 8-14	30	18	36	75.0	48
≥ 15-22	27	08	22	62.9	35
≥ 23-30	07	11	08	44.4	18
> 30	71	38	33	30.3	109
Total	167	98	146	55.1	265

The western region of Paraná State is considered to be an area of low risk in the transmission of malaria⁹, and since 1997 all the autochthonous cases were *P. vivax*. However, due to the vulnerability of the area of Itaipu Reservoir, the number of autochthonous cases of malaria can vary presenting sudden increase like the ones in the years of 1995, 1999, 2000 and 2002 (Fig. 3). Such situation was due to the constant presence of imported cases from Paraguay and the lack of jobs and professionalization also forces many workers to leave their homes and families and migrate to the Amazon Brazilian pioneering fronts, only returning at the end of the year time which corresponds to the rainy summer period that facilitates the *Anopheles* breeding places. In this way if they contracted the malaria infection they could serve as infection sources for *Anopheles* when they returned to Itaipu Reservoir region. After 1994, the cycles of sprinkling insecticide in the urban areas were interrupted, being restricted to the locations where outbreaks emerge. Such policy gave chance to the occurrence of malaria cases in the settlement of Ocoi, São Miguel do Iguçu, between 2000 and 2002. The collection of mosquitoes or anophelines were not conducted in a systematic way and not always in periods of transmission of malaria, what made difficult the correlation between the cases of malaria and the species of *Anopheles* in the investigated region. Besides, during all these years, the presence of *An. albitarsis*, *An. evansae*, *An. galvanoii* and *An. argyritarsis* was observed (Table 1). In relation to *An. darlingi*, not all papers have reported its finding (Table 1), although there is not in literature continuous data from long term collection, in different strategic points, with standardization of the types of traps and the sampled points. It is necessary to increase the entomological knowledge in the area of the Itaipu Reservoir to serve as parameter in the measures of selective control of the vector for the prevention of the epidemic outbreaks^{9,16}.

The municipalities of Foz do Iguçu, Santa Terezinha do Itaipu, Guaíra and Santa Helena and the indigenous area of São Miguel do Iguçu (Ocoi Indian Settlement) are considered by the FUNASA technicians as areas of high risk of malaria contamination. In other words, their very high vulnerability, that is, conditions which facilitate the installation of *Anopheles* breeding places, is due to the fact that they lie within a belt of 5,000 m starting from the left margin of the Reservoir and extending to the banks of the Paraná and Iguçu rivers, descending to an altitude of 260 m, varying from 113 to 258 m⁽⁸⁾. It must be emphasized that in the rainy months, from October to January, the high temperature and the humidity facilitate the installation of vector breeding places. It is still necessary to consider the touristic importance of Foz do

Iguçu, Guaíra and Santa Helena which attracts annually for that region a great number of people from different parts of Brazil and the world.

It must be emphasized that a rigorous control in the area of Itaipu is necessary, since this reservoir is the main mediate cause of *An. darlingi* proliferation, another species of *Anopheles* and of mosquitoes that could be responsible for arboviroses^{5,20}. Some control measures could undoubtedly reduce the breeding and avoid the autochthonous cases. The appropriate operation in connection with the levels of water of the reservoir should be tried to prevent the formation of swamps, the accumulation of stagnant waters along the edges of the dam, and the excesses of floating aquatic vegetation dispersion in various areas of Brazil. Malaria in the left bank of Paraná River is a focal problem. It must be approached locally with constant search for patients with prone to have malaria, providing early diagnosis, immediate treatment, cure control, development of educational actions and social mobilization to prevent the continuity of the epidemic outbreaks in the area. Concomitantly, it is necessary to plan and apply effective surveillance measures in the area of the Itaipu Reservoir.

RESUMO

Estudo retrospectivo da prevalência de malária e do gênero *Anopheles* na área de influência do reservatório de Itaipu Binacional

A importância de reservatórios de hidroelétricas e do intercâmbio humano na manutenção de focos de malária e a ocorrência do gênero *Anopheles* no reservatório de Itaipu Binacional foram os pontos destacados neste estudo retrospectivo. Os dados foram coletados de registros existentes em órgãos municipais, estadual e nacional de saúde e por revisão sistemática da literatura, no período de janeiro de 1984 a dezembro de 2003. A ocorrência de alguns surtos de malária, principalmente por *Plasmodium vivax*, e a prevalência de espécies do gênero *Anopheles* diferentes de *Anopheles darlingi* na região foram discutidos. A malária na margem esquerda do rio Paraná é um problema focal que deve ser abordado localmente através de medidas voltadas à saúde, educação e área social que previnam a continuidade da ocorrência de surtos na área. Concomitantemente, é necessário planejar e aplicar medidas efetivas de vigilância epidemiológica na área de influência do reservatório de Itaipu.

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