Changes in human schistosomiasis levels after the construction of two large hydroelectric dams in central Côte d'Ivoire

E.K. N'Goran,[1] S. Diabate,[2] J. Utzinger,[3] & B. Sellin[4]

The construction of large dams has been shown to increase the prevalence and intensity of human schistosomiasis. However, until now no study had been carried out to assess the impact of such a project in Côte d'Ivoire. For Kossou and Taabo, two large dams which became operational in the 1970s, baseline data are available on schistosomiasis prevalence in the surrounding area before dam construction, so that the changes in schistosomiasis levels can be assessed. We re-evaluated the prevalence of Schistosoma haematobium *and* S. mansoni *in November 1992, by analysing 548 urine and 255 stool samples, respectively, from schoolchildren from five villages around each lake. A marked increase in the overall prevalence of* S. haematobium *was observed, from 14% to 53% around Lake Kossou and from 0 to 73% around Lake Taabo. Baseline data for* S. mansoni *are only available for Lake Taabo, where a prevalence of 3% was found in 1979 and where the prevalence in 1992 was still low at 2%. The construction of these two large dams therefore led to little change in* S. mansoni *prevalence but to a significant increase in that of* S. haematobium.

Introduction

It has been emphasized that the construction of large dams may result in adverse health effects, of which one of the most frequently observed is a significant increase in the prevalence of human schistosomiasis (*1*). Schistosomiasis is considered to be a sensitive indicator disease since infection rates often change soon after the completion of dams (*2*). In relation to the construction of the Aswan Dam in Egypt (*3*) and of two other dams in sub-Saharan Africa (*4*), a changing pattern of schistosomiasis was observed with a shift in predominance from *Schistosoma haematobium* to *S. mansoni*. The most recent example is from Senegal, where an outbreak of *S. mansoni* was observed only 3 years after the Diama Dam became operational (*5–7*).

In Côte d'Ivoire, a total of 22 dams over 10 m high were built, mainly in the 1960s and 1970s (*1*). Despite the great environmental changes and extensive population movements that have resulted, the impact on public health in general and on schistosomiasis in particular has not been investigated so far. A rise in the prevalence of both *S. haematobium* and *S. mansoni* was expected in the villages located around Lake Kossou (*1*), but no survey data have been published. For the two artificial lakes of Kossou and Taabo, parasitological surveys on human schistosomiasis were undertaken before the dams became operational to investigate whether a change in schistosomiasis levels occurred. The overall prevalence of infection with *S. haematobium* was 14% for Lake Kossou (*8*) and zero for Lake Taabo (*9*). Baseline data for *S. mansoni* are only available for Lake Taabo, where the prevalence of infection was 3% (*9*).

WHO initiated the present study, which was undertaken in November 1992, and had two main aims. First, to re-evaluate the prevalence and intensity of schistosomiasis and to assess the changes that had occurred since the dam constructions. Second, to investigate whether the construction was followed by a shift in predominance from *S. haematobium* to *S. mansoni*.

Materials and methods

Study area

Kossou and Taabo Dams are both located in central Côte d'Ivoire on the Bandama River, the longest

[1] Maître-Assistant, Faculté des Sciences et Techniques, Laboratoire de Biologie Animale, Centre Universitaire de Cocody, 22 BP 582, Abidjan 22, Côte d'Ivoire. Correspondence should be sent to this author.

[2] Technicien, Centre Universitaire de Formation en Entomologie Médicale et Vétérinaire de Bouaké, Université de Côte d'Ivoire, Bouaké, Côte d'Ivoire.

[3] Ph.D. student, Department of Public Health and Epidemiology, Swiss Tropical Institute, 4002 Basel, Switzerland.

[4] Directeur de Recherche ORSTOM, ORSTOM/Institute Pasteur, Antananarivo, Madagascar.

Reprint No. **5810**

river in the country (Fig. 1). They became operational in 1972 and 1979, respectively. Kossou Dam is located at the southern point of the "V Baoulé", where the savanna meets the forest (*10*), while Taabo Dam is located 95 km downstream of Kossou with the water regime of Lake Taabo being determined by that of Lake Kossou.

Description of the Kossou and Taabo Dams

With a maximum height of 58 m, Kossou Dam is the highest in Côte d'Ivoire and has a total length of 1800 m. Lake Kossou extends approximately 130 km along the Bandama Blanc Valley and covers an area of 1780 km^2. The reservoir has an estimated size of 27675 × 10^6 m^3 (*11*, *12*). Taabo Dam has a maximum height of 34 m and is 7500 m long. Lake Taabo has a surface of 69 km^2 and an estimated volume of 69 × 10^6 m^3 (*12*, *13*). Both dams are classified as embankment dams and are built with earth and rockfill. They are used for hydroelectric power production.

Fig. 1. **Map of Côte d'Ivoire showing the artificial lakes of Kossou and Taabo in the centre of the country and the five study villages around each lake.**

Environmental alterations

Vast environmental alterations followed the construction of Kossou and Taabo Dams. The banks of the lakes are steep and the water covers decaying pre-reservoir vegetation, which provides an ideal food base for the snails that are the intermediate hosts for schistosomiasis. In addition, Kossou Dam leaks at its base, which has also created favourable snail habitats (*10*). Further details of the changes that occurred due to the construction of Kossou Dam have been reported elsewhere (*14*, *15*).

Study villages and subjects

Data were collected from five villages around Lake Kossou (Alaou Bassi, Angossé, Bocabo, Kossou town and Suibonou); baseline data for *S. haematobium* were available for four of these villages (*8*). Around Lake Taabo, data were collected from five villages (Ahondo, Bonikro, Taabo town, Taabo village and Tokohiri); baseline data were available for Ahondo before dam construction (*9*) and for Ahondo and Taabo village shortly after completion of the dam.

Schoolchildren were selected as the age group of interest (*16*), but in Suibonou where no school exists, a total of 54 children and young people aged 4–24 years were recruited.

Diagnostic techniques

S. haematobium infections were diagnosed by the results of a single urine filtration, as described by Plouvier et al. (*17*). More than 50 eggs per 10 ml of urine was classified as a heavy infection (*18*). *S. mansoni* infections were diagnosed by a single stool examination, applying the Kato–Katz thick-smear method (*19*). In the village of Suibonou, only *S. haematobium* infections were assessed.

Results

Kossou Dam

The prevalence and intensity of schistosomiasis in five villages around Lake Kossou are given in Table 1. A total of 290 schoolchildren were examined for *S. haematobium*. Eggs of *S. haematobium* were found in 154 subjects, giving an overall prevalence of 53%. Heavy infections were recorded in 34% of all positive subjects (53/154). A considerable range in both prevalence and intensity of infection was observed for the five villages, which emphasizes that the disease is focally distributed. The highest prevalence and intensity were observed in the village of Bocoba, where eggs of *S. haematobium* were excreted by 79%

Table 1: **Prevalence and intensity of human schistosomiasis in five villages located around Lake Kossou, Côte d'Ivoire, 1992**

Village	*Schistosoma haematobium*				*Schistosoma mansoni*	
	No. subjects examined	No. positive	Eggs/10 ml urine: <50	Eggs/10 ml urine: ⩾50	No. subjects examined	No. positive
Bocabo	53	42 (79)[a]	18 (34)	24 (45)	30	0 (0)
Angossé	42	10 (24)	7 (17)	3 (7)	42	0 (0)
Suibonou	54	34 (63)	28 (52)	6 (11)	ND[b]	—
Kossou town	67	24 (36)	17 (25)	7 (10)	21	4 (19)
Alaou Bassi	74	44 (59)	31 (42)	13 (18)	28	2 (7)
Total	290	154 (53)	101 (35)	53 (18)	121	6 (5)

[a] Figures in parentheses are percentages.
[b] ND = no children diagnosed.

of the children, and 45% of the children had more than 50 eggs per 10 ml of urine.

Examinations for *S. mansoni* were carried out on 121 schoolchildren in four villages. Eggs were found only in six children, two from Alaou Bassi and four from the village of Kossou town, resulting in a low overall prevalence of 5%.

Before Kossou Dam became operational, 1031 subjects were examined for *S. haematobium* and an overall prevalence of infection of 13.7% was found (*8*, *20*). Therefore, our data showed a highly significant increase in overall prevalence (χ_1^2 test, 1 df = 110.7; $P < 0.0001$) that was paralleled by significant increases in the villages of Bocabo (from 9% to 79%; $\chi_1^2 = 40.9$, $P < 0.0001$), Suibonou (from 9% to 63%; $\chi_1^2 = 39.2$, $P < 0.0001$) and Alaou (from 4% to 59%; $\chi_1^2 = 40.3$, $P < 0.0001$) but by only a slight, statistically insignificant increase in Angossé (from 13% to 24%; $\chi_1^2 = 2.2$, $P = 0.14$).

Taabo Dam

The occurrence of schistosomiasis in the villages selected around Taabo Dam is presented in Table 2. A total of 258 schoolchildren were diagnosed for *S. haematobium* and the overall prevalence was 73%. Very high prevalences of 95% and 93% were recorded in Tokohiri and Taabo town, respectively. Overall, 44% of the infected children excreted more than 50 eggs per 10 ml of urine.

A total of 134 schoolchildren were examined for *S. mansoni* in four villages; only three children were found positive, resulting in a low overall prevalence of 2%.

Before Taabo Dam became operational, 120 children were examined in the village of Ahondo. No eggs of *S. haematobium* were detected, but four children were found positive for *S. mansoni* (*9*). Two years after the dam became operational, 50 chil-

Table 2: **Prevalence and intensity of human schistosomiasis in five villages located around Lake Taabo, Côte d'Ivoire, 1992**

Village	*Schistosoma haematobium*				*Schistosoma mansoni*	
	No. subjects examined	No. positive	Eggs/10 ml urine: <50	Eggs/10 ml urine: ⩾50	No. subjects examined	No. positive
Tokohiri	41	39 (95)[a]	5 (12)	34 (83)	18	1 (6)
Ahondo	31	21 (68)	9 (29)	12 (39)	31	0 (0)
Bonikro	43	27 (63)	19 (44)	8 (19)	43	1 (2)
Taabo village	89	52 (58)	45 (51)	7 (8)	42	1 (2)
Taabo town	54	50 (93)	28 (52)	22 (41)	ND[b]	—
Total	258	189 (73)	106 (41)	83 (32)	134	3 (2)

[a] Figures in parentheses are percentages.
[b] ND = no children diagnosed.

dren were examined in Ahondo and another 50 children in Taabo village. Two children in each village were found with *S. haematobium* eggs but only two with *S. mansoni* eggs in Ahondo (*13*). Comparison of the baseline data before and shortly after the dam became operational with our data revealed a highly significant increase in the prevalence of *S. haematobium* infection ($P < 0.001$) but no change in that of *S. mansoni* infection, which remained low.

Discussion

There is a general agreement that the rapid environmental alterations caused by the construction of large dams often lead to a negative impact on human health. Ecological changes may not only modify the incidence, prevalence and intensity of diseases already present in a certain region, but may also result in the introduction and spread of new diseases (*1*). Changes in schistosomiasis prevalences frequently follow dam constructions and have been shown to be sensitive indicators (*2*).

A common problem in analysing possible changes is that suitable baseline data for the period preceding dam constructions are often not available. In water development projects that were implemented one or more decades previously, it frequently happens that no parasitological baseline data were collected or that the results were not published or are not accessible (*2*). This is confirmed by a large-scale study of water resource development schemes from a neighbouring country, Mali (*21*).

A difficulty in making comparisons of prevalences over time is that the methods used may have changed. In the villages around Lake Taabo the baseline data had been obtained for schoolchildren using urine filtration and the Kato–Katz method for detection of *S. haematobium* and *S. mansoni* infections, respectively (*9*, *13*). These same methods were used in our study of schoolchildren, hence, our data allow direct comparison with the baseline data for the Taabo Dam. The change observed was highly significant. In the case of Lake Kossou care is needed in comparing baseline data with our results because of differences in the age groups of subjects examined and in the diagnostic methods used. In the baseline study, schoolchildren and adults were examined by means of urine sedimentation for *S. haematobium* infections (*8*). In the present study, only schoolchildren were recruited and a single urine filtration test was used for detection of *S. haematobium* eggs (*17*). Schoolchildren are at highest risk for schistosomiasis infection and the prevalence of infection in this age group is usually higher than that in older age groups (*16*). Furthermore, it is estimated that urine sedimentation is about 20% less sensitive than urine filtration; in areas of relatively low prevalence, urine sedimentation may even be 35% less sensitive (*22*). As a result, the earlier prevalence data may be an underestimate and hence have produced an overestimate of the impact of the construction of Kossou Dam. However, even taking these limitations for Lake Kossou into consideration, the increase in prevalence of *S. haematobium* infection was still marked. Our findings for villages around both Lakes Kossou and Taabo thus show that the construction of the two large hydroelectric dams resulted in a marked increase in the prevalence of *S. haematobium*.

The increase in *S. haematobium* was not paralleled by a similar increase in *S. mansoni*. This result is in full agreement with the studies reported by Brinkmann et al. (*21*) for Mali and Tayo & Jewsbury (*23*) for Nigeria, who also found that *S. mansoni* remained stable while *S. haematobium* increased. It is interesting that in other places in Africa, *S. mansoni* has become the predominant type of schistosomiasis infection after dam construction (*3*, *4*, *7*). This difference could be due to the absence of the intermediate host snail. However, *Biomphalaria pfeifferi*, the intermediate host of *S. mansoni*, was reported to be very abundant in Lake Taabo already in the early 1980s (*13*).

Acknowledgements

We thank the doctors and other staff in the basic rural health centres of Yamoussoukro, Bouaflé and Tiassalé. WHO is thanked for financial support. Special thanks are due to Dr K.E. Mott, for constant encouragement and advice, and to J.M. Jenkins for critically reading and supplying much appreciated comments on the manuscript, as well as improving the English.

Résumé

Modification du niveau des schistosomiases humaines après la construction de deux grands barrages hydroélectriques en Côte d'Ivoire centrale

Il a été montré que la construction de grands barrages de retenue d'eau entraînait une recrudescence des schistosomiases (bilharzioses) humaines, se traduisant par une augmentation de la prévalence et de l'intensité de l'infection. Cependant, aucune étude véritable n'a été conduite pour évaluer l'impact des grands barrages réalisés en Côte d'Ivoire. Pour deux d'entre eux, on dispose de données sur les prévalences avant la mise en eau, ce qui autorise une appréciation de leur impact

sur la santé des populations riveraines. Les barrages hydroélectriques de Kossou et de Taabo ont été mis en service dans les années 1970 et les prévalences de *Schistosoma haematobium* avant la mise en eau étaient de 14% pour Kossou et de 0% pour Taabo. Les données relatives à *S. mansoni*, disponibles seulement à Taabo, font état d'une prévalence de 3% chez les enfants scolarisés. Nous avons réévalué les prévalences de *S. haematobium* et de *S. mansoni* en 1992 par analyse des urines et des selles de 548 et 255 enfants d'âge scolaire, provenant respectivement de 5 villages situés autour de chacun des lacs de retenue. Une augmentation considérable de la prévalence de *S. haematobium*, pouvant atteindre 53% et 73%, a été observée autour des lacs de Kossou et de Taabo. La prévalence de *S. mansoni* était faible (5% et 2% respectivement). En conclusion, il ressort que la construction de ces deux grands barrages a eu un impact négatif sur la santé des populations humaines en ce qui concerne *S. haematobium*; pour le moment, on n'observe toutefois par de substitution de cette forme par *S. mansoni*. Cette situation mérite donc d'être étudiée plus attentivement, avec des investigations plus précises.

References

1. **Hunter JM et al.** *Parasitic diseases in water resources development: the need for intersectoral negotiation.* Geneva, World Health Organization, 1993.
2. **Huang Y, Manderson L.** Schistosomiasis and the social patterning of infection. *Acta tropica*, 1992, **51**: 175–194.
3. **Abdel-Wahab MF et al.** Changing pattern of schistosomiasis in Egypt, 1935–79. *Lancet*, 1979, **2**: 242–244.
4. **Mott KE et al.** New geographical approaches to control of some parasitic zoonoses. *Bulletin of the World Health Organization*, 1995, **73**: 247–257.
5. **Picquet M et al.** The epidemiology of human schistosomiasis in the Senegal river basin. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 1996, **90**: 340–346.
6. **Stelma FF et al.** Epidemiology of *Schistosoma mansoni* infection in a recently exposed community in northern Senegal. *American journal of tropical medicine and hygiene*, 1993, **49**: 701–706.
7. **Talla I et al.** Outbreak of intestinal schistosomiasis in the Senegal river basin. *Annales de la Société Belge de Médecine tropicale*, 1990, **70**: 173–180.
8. **Richard-Lenoble D, Picq JJ.** *Enquête bilharziose réalisée dans les régions du port de San Pedro et du barrage de Kossou, République de Côte d'Ivoire du 28 Octobre 1970 au 12 Novembre 1970.* Document technique OCCGE/4794, 1970.
9. **Haller L.** Affections parasitaires. *Acta tropica*, 1980, **37** (suppl. 11): 41–55.
10. **Doumenge JP et al.** *Atlas of the global distribution of schistosomiasis.* Geneva, World Health Organization, 1987.
11. **Deschiens R, Cornu M.** Commentaires écologiques et épidémiologiques concernant les bilharzioses et le lac de retenue de Kossou (Côte d'Ivoire). *Bulletin de la Société de Pathologie Exotique*, 1976, **69**: 163–169.
12. *World register of dams: 1988 updating.* Paris, International Commission on Large Dams, 1989.
13. **Sellin B, Simonkovich E.** Schistosomiases et barrages en Côte d'Ivoire. In: De l'épidemiologie à la géographie humaine. Table ronde "tropiques et santé". *Travaux et documents de Centre d'étude de Géographie Tropicale*, 1983, **48**: 209–214.
14. **Picot H.** L'aménagement de la Vallée du Bandama: problèmes sanitaires et sociaux. *Bulletin de la Société de Pathologie Exotique*, 1976, **69**: 156–162.
15. **Scott D, Chu KY.** *Research in the epidemiology and methodology of control of schistosomiasis in man-made lakes: report on a visit made from the project based in Ghana to Lake Kossou in Ivory Coast from 18 to 25 May 1974.* Geneva, World Health Organization, 1974, unpublished document MPD/74.7.
16. *The control of schistosomiasis: second report of the WHO Expert Committee.* Geneva, World Health Organization, 1993 (WHO Technical Report Series, No. 830).
17. **Plouvier S, Leroy J-C, Colette J.** A propos d'une technique simple de filtration des urines dans le diagnostic de la bilharziose urinaire en enquête de masse. *Médecine tropicale*, 1975, **35**: 229–230.
18. *Basic laboratory methods in medical parasitology.* Geneva, World Health Organization, 1991.
19. **Katz N, Chaves A, Pellegrino J.** A simple device for quantitative stool thick-smear technique in *Schistosoma mansoni*. *Revista do Instituto de Medicina Tropical de São Paulo*, 1972, **14**: 397–400.
20. **Moreau J-P et al.** Repartition des schistosomiases dans les pays francophones d'Afrique de l'ouest. *Médecine tropicale*, 1980, **40**: 23–30.
21. **Brinkmann UK, Korte R, Schmidt-Ehry B.** The distribution and spread of schistosomiasis in relation to water resources development in Mali. *Tropical medicine and parasitology*, 1988, **39**: 182–185.
22. **Webbe G, El Hak S.** Progress in the control of schistosomiasis in Egypt 1985–1988. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 1990, **84**: 394–400.
23. **Tayo MA, Jewsbury JM.** Malumfashi endemic diseases research project, IV: Changes in snail population following the construction of a small dam. *Annals of tropical medicine and parasitology*, 1978, **72**: 483–487.