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

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*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

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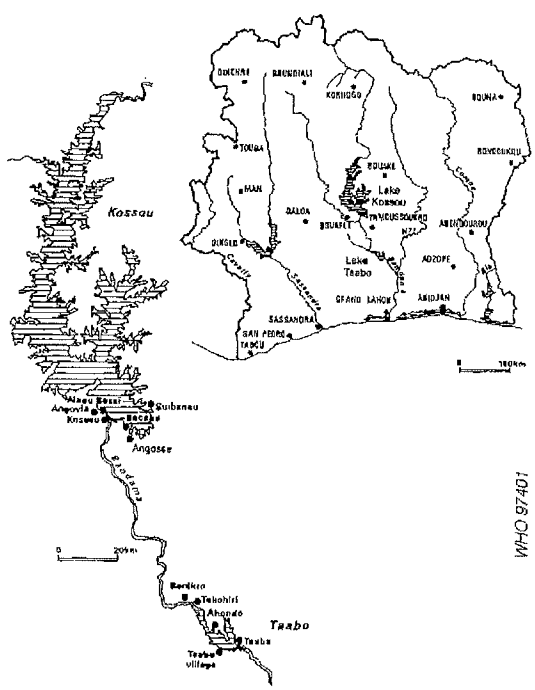
Reprint No. **5810**

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 $27675 \times 10^6 m^3$ (*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 $69 \times 10^6 m^3$ (*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**

| | *Schistosoma haematobium* | | | | *Schistosoma mansoni* | |
|---|---|---|---|---|---|---|
| | | | Eggs/10 ml urine | | | |
| Village | No subjects examined | No positive | <50 | ≥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 ($\chi_1^2$ 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**

| | *Schistosoma haematobium* | | | | *Schistosoma mansoni* | |
|---|---|---|---|---|---|---|
| | | | Eggs/10 ml urine: | | | |
| Village | No. subjects examined | No positive | <50 | ≥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.

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WORLD HEALTH ORGANIZATION PUBLICATIONS

# Aluminium

This book evaluates the risks to human health and the environment posed by exposure to aluminium. In view of recent evidence suggesting a role of aluminium exposure in the development or progression of Alzheimer's disease, the report gives particular attention to the methodological strengths and weaknesses of epidemiological studies and the relevance to humans of animal data demonstrating neurotoxicity in several species. Over 700 studies were assessed in an effort to resolve current uncertainties about risks to the general population, exposed workers, the elderly, and several other susceptible subpopulations

Background information is provided in the opening sections, which summarize what is known about sources of environmental and human exposure and discuss the main routes and levels of exposure. The report notes that aluminium is released to the environment both by natural processes and from anthropogenic sources. As aluminium is a major constituent of the earth's crust and the third most common element, natural processes far outweigh the contribution of anthropogenic sources Mobilization of aluminium through human activities is mostly indirect and occurs as a result of emission of acidifying substances such as sulfur dioxide and nitrogen oxides. The report cites enhanced wind and water erosion from cultivated land, notably when fallow, as having the largest anthropogenic impact on aluminium movement in the environment.

Information on the many industrial uses of aluminium and its compounds is followed by a discussion of the physicochemical and geological factors that affect aluminium mobility and subsequent transport within local environmental systems. Concerning sources of human exposure, ingestion of aluminium present in food is identified as the main source for the general population, with food and beverages accounting for 90–95% of total daily intake. Much higher exposures are noted to occur in certain occupations and in people taking antacids and buffered analgesics. The report also cites recent evidence indicating that drinking-water is a minor source of human exposure.

A review of human and animal data on kinetics and metabolism concludes that aluminium and its compounds are poorly absorbed in humans; the highest levels of aluminium have been detected in the lungs, where it is present as inhaled insoluble particles Urine is the most important route of elimination. In animals, aluminium is distributed in most organs within the body, with accumulation occurring mainly in bone at high dose levels.

An evaluation of the large body of data from toxicity studies in experimental animals found no evidence that aluminium is carcinogenic and no evidence of fetotoxicity or adverse effects on reproduction. Considerable evidence indicates that aluminium is neurotoxic, with adverse effects on neurological development and brain function. Studies have also demonstrated toxic effects on bone, and osteomalacia, as it presents in man, has been consistently observed. The report found no evidence that exposure induces a neurological pathology with the morphological and biochemical characteristics of Alzheimer's disease.

The evaluation of effects on human health gives particular attention to several epidemiological studies carried out to test the hypothesis that aluminium in drinking-water is a risk factor for the development or acceleration of Alzheimer's disease and a possible cause of impaired cognitive function in the elderly and in occupationally-exposed workers. Following a critical assessment of the design of these studies, all of which have flaws, the report concludes that, while a possible association cannot be totally dismissed, currently available evidence does not support a causal relationship between Alzheimer's disease and exposure to aluminium in drinking-water. The hypothesis that particular exposures, either occupational or via drinking-water, may be associated with non-specific impaired cognitive function was likewise judged to be inadequately supported by available data.

While aluminium has not been shown to pose a risk to healthy, non-occupationally exposed humans, abundant studies demonstrate that patients with renal failure are at risk of neurotoxicity and other disorders from aluminium present in haemodialysis fluid and pharmaceutical products. As iatrogenic aluminium exposure has been shown to pose a hazard to patients with chronic renal failure and to premature infants, the report concludes that every effort should be made to limit exposure in these groups.

Concerning risks to the environment, the report concludes that concentrations of aluminium can increase to levels resulting in adverse effects on both aquatic organisms and terrestrial plants in some areas subject to strong acidifying inputs.

**Aluminium**
*Environmental Health Criteria*, No 194
1997, xx + 282 pages
English with summaries in French, Spanish
ISBN 92 4 157194 2, order no. 1160194
Sw.fr. 60.–/US $54.00, in developing countries: Sw fr 42 –