**EFFET DE L’ASSAINISSEMENT ECOLOGIQUE SUR LA PREVALENCE DE LA SCHISTOSOMIASIS UROGENITALE DANS LES PERIMETRES IRRIGUES DE LOPE ET NIANRA A KATIOLA**

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**RESUME :**
L’Assainissement Ecologique consiste à percevoir les déchets solides et liquides non pas comme des rebuts, mais comme des ressources à valoriser. Ainsi, dans les périmètres irrigués de Lopé et Nianra à Katiola, un projet a permis l’utilisation de l’urine comme fertilisant. L’objectif de cette étude était d’explorer si l’assainissement écologique, par la destruction des œufs de schistosome pourrait limiter la transmission de la schistosomiasis urinale dans ces périmètres irrigués.


**Résultats :** La prévalence de la schistosomiasis urinale sur l’ensemble des sites d’étude était de 1.04%, avec des proportions de 0.52% à Lopé, et 1.56% à Nianra. Après 45 jours d’hygiénisation, la charge parasitaire des échantillons d’urines contaminées est passée de 24 œufs/10ml à 00 œuf / 10ml. 30.5 m² d’urine collectée mensuellement et hygiénisée, a été utilisée pour la fertilisation des parcelles expérimentales de Lopé et Nianra dans le cadre du projet Ecosan.

**Conclusion :** L’assainissement écologique n’était pas mis en cause dans la présence de la schistosomiasis urinale sur les périmètres irrigués de Lopé et Nianra.

**Mots clés :** assainissement écologique - urine- périmètre irrigué- schistosomiasis urinale

**ABSTRACT :**
Ecological sanitation consists in perceiving solid and liquid waste not as waste, but as resources to be valorized. Thus, in the irrigated perimeters of Lopé and Nianra in Katiola, a project has allowed the use of urine as fertilizer. The objective of this study was to explore whether ecological sanitation, through the destruction of schistosome eggs, could limit the transmission of urogenital schistosomiasis in these irrigated perimeters.

**Material and method:** The descriptive study of the ecological sanitation circuit of Katiola (production, collection and transport, hygienization by storage and valorization of urine) of the irrigated perimeters of Lopé and Nianra took place from 15 to 30 July 2010. Through this circuit, urine was collected from households and urinal boxes installed in the town of Katiola from February to December 2010, to be used, after sanitization, to fertilize the rice fields. At the same time, a cross-sectional epidemiological study was conducted from June 26 to July 5, 2010 to screen 384 people attending the hydro-agricultural facilities of Lopé and Nianra. Urine samples contaminated with Schistosoma haematobium eggs were collected from people who tested positive for urogenital schistosomiasis and analyzed to ensure the sanitary quality of the urine to be used as biofertilizer. Parasitological analyses of these urine samples were performed every 15 days, during 45 days of sanitation from July 06 to August 20, 2010.

**Results:** The prevalence of urogenital schistosomiasis in all study sites was 1.04%, with proportions of 0.52% in Lopé, and 1.56% in Nianra. After 45 days of sanitization, the parasite load of contaminated urine samples decreased from 24 eggs/10ml to 00 eggs/10ml. 30.5 m² of urine collected monthly and sanitized, was used for fertilization of the experimental plots in Lopé and Nianra within the framework of the Ecosan project.

**Conclusion:** Ecological sanitation was not implicated in the presence of urogenital schistosomiasis in the rice fields of Lopé and Nianra.

**Key words:** ecological sanitation - urine - irrigated perimeter - urogenital schistosomiasis
1. INTRODUCTION

According to WHO, sanitation is the collection and hygienic disposal of excreta and liquid waste from the community to protect the health of individuals. The new and best approach to sanitation is Ecological Sanitation (EcoSan), which is to avoid soiling [1]. This means, at the household level, treating waste from the beginning by separating faeces from urine on the one hand and other wastewater on the other. This implies giving priority to waste recovery, particularly in agriculture [2].

The problem to be addressed is the control of sanitary risks related to the use of human excreta in agriculture in view of the epidemiological problems that they could generate. It is therefore essential to sanitize human excreta before collecting and reusing them because some pathogens in urine can cause typhoid, paratyphoid and bilharzia [3, 4].

The use of urine as a fertilizer in irrigated rice cultivation may increase the spread of schistosomiasis, because the disease whose public health importance and prevalence have increased most as a result of water development in Africa is schistosomiasis [5]. Schistosomiasis is one of the most widespread parasitic diseases in the world with major health and socio-economic implications in developing countries, where it is a major public health problem [6]. The issue of urine as a fertilizer in ecological sanitation in irrigated areas needs to be treated with great attention as urine is the main source of schistosomiasis spread [4].

The Ecosan project initiated in Katiola by the Water and Sanitation Agency for Africa in Ivory Coast (WSA-Côte d’Ivoire) is taking place in an area that contains two hydro-agricultural dams and is already endemic to urogenital schistosomiasis because cases of urogenital schistosomiasis are regularly encountered there [7, 8]. The prevalence of urogenital schistosomiasis is also 0.008% in the department of Katiola [9]. The research question is therefore whether urine used as a fertilizer in irrigated areas is likely to increase the prevalence of urogenital schistosomiasis in the populations that frequent these rice-growing areas. The objective of this study was to explore whether ecological sanitation, through the destruction of schistosome eggs, could limit the transmission of urogenital schistosomiasis in the irrigated perimeters of Lopé and Nianra in Katiola.

2. MATERIAL AND METHOD

2.1. Study area

The Department of Katiola, created by law n°69-241 of June 9, 1969, is located in the center north of Côte d’Ivoire, 45 km north of Bouaké on the Abidjan - Korhogo axis. Its surface area is 9,420 km² [10]. The boundaries of the department are: Bouaké to the south, Ferkkessedougou to the north, Dabakala to the east, Korhogo to the west. The study area (figure 1) consists of the following three localities in the department:

- the rice-growing area of Nianra (sub-prefecture of Timbé) with a surface area of 300 ha, 7 km from the town of Katiola where the Nianra hydro-agricultural dam is located
- the rice-growing perimeter of Lopé (Katiola sub-prefecture) with an area of 70 ha located 3 km from the town of Katiola where the Lopé hydro-agricultural dam is located;
- the city of Katiola where the urine collection took place with households in the neighborhoods of Nangnankaha, Kaklinkaha, Pedikaha, Nandieplekaha and Mangoroso.

2.2 Collection of Ecological Sanitation Data

2.2.1 Sample size

The descriptive study of the stages of the ecological sanitation circuit took place from 15 to 30 July 2010. Through this circuit, urine was collected from households and urinal boxes installed in the town of Katiola, from February to December 2010, to be used after hygienization, to fertilize rice fields.

The number of households from which urine was collected was determined using the Slovin formula, as the size of the study population is known but no information is available on the behavior of this population. This sampling formula is as follows with a 95% confidence interval and a 7% margin of error.

\[ n = \frac{P_a}{1+P_a e^2} \]

with: n: number of households; Pa: population size and e = margin of error

\[ n = \frac{119.000}{(1+119.000 \times 0.07^2)} \] and therefore n = 204 households to be surveyed.

2.2.2 Urine production

In order to collect urine for fertilization of irrigated areas, the production facilities consist mainly of urinal boxes and bidurs. For those using the urinal boxes, 20 to 25 liter cans with funnels (bidurs) were placed in the urinal boxes built in the town of Katiola by the Ecosan project. The 25 urinal boxes were installed in various parts of the city, precisely near cabarets, maquis and bars. Other 10 liter cans were distributed to households located in the neighborhoods of the city of Katiola, namely Nangnankaha, Kaklinkaha, Pedikaha, Nandieplekaha and Mangoroso at an average rate of 3 cans/household. These households were chosen because they agreed to donate urine after the Ecosan project had explained it to the population (n = 204) over the period from February to December 2010. The cans were grouped together for collection and transport to the rice field.

2.2.3 Urine collection and transport

At the initiative of the Ecosan project, the urine was collected with wheelbarrows by pre-collectors trained for this task. This collection and transportation of urine was carried out from February to December 2010. The cans filled with urine were grouped together at different points in the city and then transported to the irrigated areas of Lopé and Nianra. The urine collected was stored near each of the Ecosan project rice fields in Lopé and Nianra. After collection and grouping of the cans stored in the urinal boxes and those distributed to households in the town of Katiola, the urine was generally...
transported to the rice fields of Lopé and Nianra by motorcycle or vehicle.

2.2.4 Hygienization by storage of urine

Hygienization or storage guarantees the sanitary quality of urine that does not present any health risk. This sanitary quality of urine is verified in the laboratory by a standardized procedure during the storage period [2, 12-14]. In this study, in order to make urine a biofertilizer without health risks, all individuals screened positive for urogenital schistosomiasis during the prevalence survey were systematically subjected to a second study. For this purpose, 2 liters of urine were collected from these screen-positive individuals. This amount of urine was divided into 40 jars of 50 ml filled with urine [2]. Each urine jar was identified by a number. Hygienization of urine samples contaminated with *Schistosoma hematothium* eggs was done at room temperature, protected from the sun for 45 days from July 6 to August 20, 2010. In these contaminated samples, it was necessary to follow the disappearance of *Schistosoma haematobium* eggs as a function of the hygienization time. The evolution of the parasite load is the parameter observed under the microscope, at a magnification x 10 and x 40, by adding 1% lugol. Urine analysis by the urine centrifugation technique was carried out at 15-day intervals [15] starting from the reference period D0 and then at D15, D30 and D45. After verification of the sanitary quality of the urine in the laboratory, at each crop cycle, the urine was stored or hygienized for 45 days in 1 m³ drums in the hydro-agricultural perimeters before application or use in the rice fields. Hygienization was carried out during the entire period from February to December 2010.

2.2.5 Urine valorization

The quantity of urine stored was 4 m³ for Lopé and 2 m³ for Nianra. The fertilizer called "ferturine" was obtained. The use of urine on the irrigated perimeters allowed for soil fertilization. This was done at each crop cycle from August to December 2010. This fertilization is done by injecting the urine into the irrigation water with a dilution of 1/100. The quantity and dose were determined according to the area. The norm in general was 4 drums of 1m³/ha applied in two stages of the crop cycle, 15 days before the seedling and 60 days after the run, as a replacement for urea. The experimental area of the WSA agency was 2 ha in Lopé on a total area of 70 ha and 0.25 ha in Nianra on a total area of 300 ha.

2.3 Collection of epidemiological data

2.3.1 Sample size of the epidemiological survey

The epidemiological survey was a descriptive cross-sectional study conducted from June 26 to July 5, 2010. The sample size was determined using this formula:

\[ N = \frac{t^2p(1-p)}{e^2} \]

N = expected sample size; t = confidence level = 1.96; p = estimated population proportion = 0.5; e = margin of error (set at 5%); N = 384 persons to be surveyed in Lopé and Nianra, with 192 persons per locality.

2.3.2 Collection of urine samples

In Lopé and Nianra, urine samples were collected from the rice populations of the irrigated areas before their use for fertilization, over the period from June 26 to July 5, 2010. The inclusion criteria were any person who consented to the study and resided for at least 6 months in the study area. The urine samples collected in sterile and transparent 50 ml single-use jars were those of the morning, after a moderate effort in order to promote the excretion of urine eggs and improve the sensitivity of laboratory examinations [16]. The pills boxes were collected no later than 9:00 a.m. in a cooler and transported immediately to the laboratory at Katiola Hospital where microscopic examinations began at 11:00 a.m. In order to avoid biases on screened persons, a survey form was elaborated with information on the locality, the date and time of the survey, the names of the persons screened and the clinical signs. Observation included sex, age, urine color, itching, headache, fever, pain during micturition, and hematuria for those who volunteered for the epidemiological screening.

For the collection of data in the field, the person in charge of the collection of the Ecosan system in Katiola and the principal investigator were involved.

2.3.3 Screening for urogenital schistosomiasis

Screening for urogenital schistosomiasis was carried out from June 26 to July 5 2010. The macroscopic examination of the appearance of the urine allowed us to know the color of the urine of the screened person and to detect the presence of hematuria. Microscopic examination of urine performed at the biological analysis laboratory of Katiola General Hospital using the urine centrifugation technique also allowed the detection of hematuria. Urine in hemolysis tubes was centrifuged at 2500 g for 10 minutes at a temperature of 25°C. The sedimentation pellet is subjected to microscopic observation at x 10 and x 40 magnification by addition of 1% lugol. The drops are placed on slides covered with slides, using pipettes. The result reveals the presence or absence of an ovoid embryonic egg with a thin shell of 150 µ by 60 µ, with a terminal spur.

2.4 Ethical considerations

This study received permission from the National Committee on Ethics in Health and Life Sciences (CNESVS) of Côte d'Ivoire. During interviews with rice farmers, privacy was respected by the investigator and responses were recorded on the survey forms. Data were collected in a confidential manner and the anonymity of the individuals was respected. Individuals agreed to participate voluntarily in the study and those who tested positive for urinary bilharzia were treated with Praziquantel by the project.

2.5 Data processing and analysis

The data concerned the quantity of urine collected, the parasite load, the sex, the age and the hematuria of the persons screened. The processing and analysis of these data was done...
with EpiInfo software version 3.5.1 (Centers for Disease Control and Prevention; Atlanta, USA). For each location, the quantity of urine collected in liters (l) and the time taken was calculated. The kinetics of the evolution of the parasite load every 15 days as well as the prevalence of urogenital schistosomiasis according to the demographic variables of the respondents were also calculated. The Fisher-Exact test was used to compare proportions between sexes and localities.

3. RESULTS

3.1 Urine production
A total of 236 urine production facilities, including 25 urinal boxes, were set up in the city of Katiola and 211 bidurs were distributed to households.

The 25 urinal boxes produced 515 liters of urine between 4 and 11 days. The average monthly urine production by the boxes was estimated at 2,581.5 liters, or about 2.6 m$^3$ of urine (Table I).

The 211 bidurs distributed to households produced a total of 2,410 liters (about 2.4 m$^3$) in a time interval of one to eleven days. The average monthly urine production from the bidurs was estimated to be 30,317.1 liters, or about 30.3 m$^3$.

Households provided almost 5 times the amount of urine produced by urinal boxes in a shorter time interval.

3.2 Prevalence of urogenital schistosomiasis in Lopé and Nianra

The prevalence of urogenital schistosomiasis in both localities (Lopé and Nianra) was 1.04%.

The prevalence of urogenital schistosomiasis was higher in Nianra (1.56%) compared to Lopé (0.52%) (Table II). There was no significant difference in the prevalence of urogenital schistosomiasis between subjects in Lopé and Nianra ($\chi^2 = 0.311; p$ value $= 0.623$), male and female subjects ($\chi^2 = 0.093; p = 0.760$), and subjects of different age groups ($\chi^2 = 0.481; p$ value $= 0.632$).

3.3 Sanitary quality of urine

According to Table III, the different parasite loads of the urine samples analyzed at step time ranged from 1 egg/10ml to 24 eggs/10ml. After 15 days of hygienization (D15), parasite loads ≤ 9 eggs/10ml of urine samples become zero. In contrast, parasite loads > 9 eggs/10 ml of the remaining urine samples cancelled out after 30 days of hygienization (D30). At D45, the urine samples are still free of Schistosoma haematobium eggs.

**DISCUSSION**

During the Ecosan project, the monthly quantity of urine produced in the town of Katiola was estimated at about 33 m$^3$. Urine production from the urinal boxes averaged 2.5 m$^3$, while household urine production was estimated at 30.5 m$^3$, or almost 12 times the urine production from the urinal boxes. This result can be explained by the fact that there were several people in a household using the bidurs. This is supported by the fact that urine production times were shorter in households than in the urinal boxes in the five collection neighborhoods identified in the town.

Urine production in the Nangnankaha neighborhood was higher than in the other neighborhoods because the people there were overwhelmingly supportive of the Ecosan project. The collected urine was stored for use as fertilizer [4, 12, 17]. With the Ecosan project, 4 m$^3$ and 2 m$^3$ of urine, respectively, were spread as biofertilizer on the experimental parcels in Lopé and Nianra for each rice crop cycle.

The subjects chosen for the epidemiological survey came from two localities in the Katiola region where hydro-agricultural dams have been built. The Nianra dam is the larger of the two dams, which explains the extent of the perimeter developed for rice production. In this location, a prevalence of urogenital schistosomiasis of 1.56% was observed, compared to 0.52% in Lopé where the hydro-agricultural development is less extensive. This situation could be explained by the large extent of the hydro-agricultural development, which would contain many more sites for mollusks of the genus bulinus, an intermediate host of parasitosis such as urogenital schistosomiasis. This would expose more people working on the rice fields to the potential risks of infection with Schistosoma haematobium. This result is consistent with previous studies conducted in Ivory Coast and Burkina Faso which presented hydro-agricultural dams as risk factors for schistosomiasis transmission [8, 18].

Screening of a sample of 384 people in the rice-growing populations of two localities, Lopé and Nianra, gave an overall prevalence of 1.04% of people with urogenital schistosomiasis. In a review, the prevalence of schistosomiasis was estimated for the whole of Ivory Coast at between 20% and 25% [19]. The prevalence of urogenital schistosomiasis observed in the study area is low compared to that observed nationally. This low proportion could be explained by the draining of irrigation canals by rice farmers when the rice crops are finished in order to avoid the proliferation of mollusc breeding sites, intermediate hosts of the disease. Another reason is that the population of this locality, thanks to some awareness campaigns conducted by the local branch of the National Institute of Public Hygiene (INHP), has a better understanding of the dangers of bathing or defecating in water bodies.

However, this prevalence, although low, provides information on the presence of urogenital schistosomiasis in the irrigated perimeters of Lopé and Nianra and allows us to say that the existence of the disease is linked to the ecosystem and cultivation practices, especially in the hydro-agricultural developments. These results are in agreement with the work carried out in Ivory Coast which have blamed hydro-agricultural developments for the increase in the prevalence of urogenital schistosomiasis [5, 20, 21]. Other studies in Côte d’Ivoire, among school children, have also presented hydro-agricultural dams as reservoirs of intermediate host mollusks of the disease [22]. In the sub-region, notably in Mali, studies have shown that hydro-agricultural dams favor schistosomiasis endemic [23, 24].
In Lopé, the epidemiological survey revealed that the proportion of urogenital schistosomiasis was 0.52% for 192 people screened (adults and children). In this locality, no woman was affected by this disease. This could be justified by the fact that women wear protective equipment such as boots on the irrigated rice fields. The prevalence of urogenital schistosomiasis was 0.97% in men. Specifically in Lopé, the only positive case was recorded in a young boy. The presence of the disease in males could be explained by the fact that young boys escape the vigilance of their parents to play in the drainage waters of the hydro-agricultural perimeter. This result is consistent with that obtained in Cameroon, where a relationship was found between parasite carriage and sex [25]. The predominance of boys, according to this author, could be explained by the fact that they play more in the water than girls, who are more concerned about their bodies.

In Nianra, the proportion of bilharzia was 1.56% for 192 people screened (adults and children) with a male/female ratio of 1.27. Among men, it was 0.92% compared to 2.38% among women. Women are more affected by urogenital schistosomiasis than men. This situation can be explained by

<table>
<thead>
<tr>
<th>PL: Parasitic load</th>
<th>D0: Day 0</th>
<th>D15: Day 15</th>
<th>D30: Day 30</th>
<th>D45: Day 45</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL D0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>PL D15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PL D30</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PL D45</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table I: Distribution of average production of boxes and households, by day, week and month

<table>
<thead>
<tr>
<th>Districts</th>
<th>Num</th>
<th>Ber</th>
<th>Qty (liters)</th>
<th>Time Prod (days)</th>
<th>Aver Prod (days)</th>
<th>Aver Prod (weeks)</th>
<th>Aver Prod (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaklinkaha</td>
<td>11</td>
<td>245</td>
<td>[4 ; 11]</td>
<td>41.76</td>
<td>292.32</td>
<td>1,252.8</td>
<td>25</td>
</tr>
<tr>
<td>Nandieplekah</td>
<td>3</td>
<td>50</td>
<td>[4 ; 7]</td>
<td>9.82</td>
<td>68.74</td>
<td>294.6</td>
<td>40</td>
</tr>
</tbody>
</table>

Table II: Prevalence of urogenital schistosomiasis in the both localities

<table>
<thead>
<tr>
<th>By Sex</th>
<th>Female</th>
<th>Male</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>89</td>
<td>0</td>
<td>192</td>
</tr>
<tr>
<td></td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
</tr>
<tr>
<td></td>
<td>84</td>
<td>0</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>2 (2.38)</td>
<td>0 (0.00)</td>
<td>2 (1.05)</td>
</tr>
<tr>
<td></td>
<td>173</td>
<td>0</td>
<td>173</td>
</tr>
<tr>
<td></td>
<td>2 (1.15)</td>
<td>0 (0.00)</td>
<td>2 (1.15)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>By age (years)</th>
<th>Female</th>
<th>Male</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-10</td>
<td>51</td>
<td>1</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>1 (1.96)</td>
<td>0 (0.00)</td>
<td>1 (1.96)</td>
</tr>
<tr>
<td>10-14</td>
<td>74</td>
<td>0</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
</tr>
<tr>
<td>15-19</td>
<td>28</td>
<td>0</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
</tr>
<tr>
<td>≥ 20</td>
<td>39</td>
<td>0</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
<td>0 (0.00)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>n : number of subjects tested positive</th>
<th>%: percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tableau III: Evolution of the parasitic load of urine samples as a function of hygienization time
the fact that the women of Nianra do not use boots, but rather simple shoes that allow their feet to show through, thus putting them in contact with the irrigation water. This defective protection in this hydro-agricultural perimeter predisposes them to disease. The safety measure taken by the women of Lopé was not well applied by those of Nianra. The results obtained in Lopé and Nianra are in agreement with those of other studies where parasitic infestation was related to sex [26, 27].

However, according to the results obtained for the two localities (Lopé and Nianra), there is no significant difference between the proportion of men and women with urogenital schistosomiasis ($\chi^2 = 0.093; p = 0.760$). The male/female sex ratio was 1.21 (211/173), i.e., almost one man for every woman. In effect, both men and women are constantly on the irrigated rice fields and are both at risk for bilharzia infection. This result confirms those of Grand Bassam, Toumodi and Agboville, for whom parasitic infestation is not related to gender [28-30].

The ages of the recruited individuals ranged from 5 to over 60 years. Of the four subjects found positive in the study area, one was a 5-year-old child in Lopé, one was a 13-year-old adolescent, and two were adults aged 33 and 50 years, respectively ($\chi^2 = 0.481; p = 0.632$). These age results showed that all age groups are vulnerable to schistosomiasis in this region. This can be explained by the professional activity performed by these people in the study area. Indeed, the populations of Lopé and Nianra are mostly rice farmers because of the hydro-agricultural developments in this region of Ivory Coast. The children as well as their parents are found at the level of these installations for the agricultural activities. This exposes these two categories of people to potential risks of contamination. This result is consistent with that found in children in two villages in Burkina Faso where parasitic infestation was also not related to age [31]. However, similar studies have shown a link between age and the prevalence of urogenital schistosomiasis. We can cite the case of school children in Congo, Senegal, Mali and hematuric patients in Ivory Coast where children are more affected than adults and this can be explained by the fact that children and adolescents bathe more in rivers and swamps [32-35].

With the Ecosan project, as mentioned above, 4 m$^3$ and 2 m$^3$ of urine, respectively, are spread on the experimental plots in Lopé and Nianra for each rice crop cycle. Despite the use of this large quantity of urine on the Lopé and Nianra plots, a low prevalence of urogenital schistosomiasis (1.04%) was noted. This prevalence of urogenital schistosomiasis found in our study, although low, is nevertheless higher than that of the department of Katiola which was 0.008% before the Ecosan Project [9]. Therefore, this proportion of urogenital schistosomiasis observed in Lopé and Nianra is a good indicator that should alert us to measures to be taken to control this disease in this area.

Our results also showed that the hygienization phase by storage of urine over the period of 45 days allows the destruction of all eggs of *Schistosoma haematobium* responsible for urogenital schistosomiasis. During storage, the urea in the urine is dissociated and forms ammonium/ammonia. Thus, the urine becomes alkaline and the pathogens can be eliminated. Our results regarding ecological sanitation are in agreement with studies conducted in Burkina Faso and Sweden, which showed that storing urine for more than one month destroyed most pathogens [12, 15, 17, 36, 37]. These results allow us to conclude that after hygienization, the application of urine as fertilizer in its valorization phase on irrigated perimeters would not lead to the transmission of urogenital schistosomiasis and other pathologies when all precautions are taken. In view of our results, we can say that ecological sanitation through urine hygienization could be an effective means of controlling bilharzia because it breaks the transmission cycle of this disease. On the other hand, in the absence of ecological sanitation, contaminated urine released into the environment (hydro-agricultural facilities, waterways) maintains the transmission cycle of urogenital schistosomiasis.

However, this study has some limitations, despite the convincing results obtained. Indeed, the study revealed the sanitary quality of urine only by an absence of *Schistosoma haematobium* eggs after hygienization. But, it should be noted that the health risks associated with the use of ferturine by the rice growing population of Lopé and Nianra are minimal, because sanitization of urine over 30 days is sufficient to inhibit pathogenic microorganisms such as Salmonella, *Escherichia coli*, and other Gram-negative bacteria through the effect of temperature and high pH (about 9), combined with ammonia [13, 38].

In addition, the Ecosan project's experimental plots cover only 2 ha in Lopé and 0.25 ha in Nianra, for total areas of 70 ha and 300 ha, respectively. Hygienized urine, used as a fertilizer on these small areas of the WSA rice fields, cannot be the cause of *Schistosoma haematobium* infection. Moreover, those who tested positive had their rice plots far away from the experimental plots where urine fertilization was taking place. This result also suggests that there is no correlation between urine fertilization in irrigated rice production and transmission of urogenital schistosomiasis. Better still, the use of urine as a fertilizer on irrigated perimeters is an interesting approach to encourage, given the good harvests achieved on the Ecosan project's experimental plots in Lopé and Nianra. Our results are in agreement with other works in Niger, Tchad, Burkina Faso and Ivory Coast that have shown that urine is a very good fertilizer [2, 39-43]. However, one of the limitations of this study is the absence of a before and after study that would have better situated the implication of ecological sanitation in the transmission of urogenital schistosomiasis. However, in the department of Katiola, the prevalence of urogenital schistosomiasis after the Ecosan project was 0.008%, which means that it was practically identical to that observed before the project [9, 44]. This could lead to the conclusion that ecological sanitation in the transmission of urogenital schistosomiasis...
sanitation was not implicated in the presence of schistosomiasis.

The Ecosan project is within everyone’s reach because it takes into account all social strata (children, youth, adults, women, men) for the collection of urine for fertilization of irrigated areas. The results of this study are beneficial to all agricultural populations in general, but can be applied in particular to rice farmers and all those who work in hydroagricultural schemes.

In the perspective of sustainable development, while preserving the environment, Ecosan systems allow for the improvement of health by minimizing the introduction of pathogens from human excreta into the water cycle, the preservation of fertility and the improvement of agricultural productivity [45].

CONCLUSION

The Ecosan project initiated by the WSA Ivory Coast agency in Katiola has enabled the production of ferturine, a fertilizer used on rice fields. The monthly production of urine in Katiola by households is greater than that produced in urinal boxes. The epidemiological survey of rice-growing populations in Lopé and Nianra using this fertilizer found a low prevalence of urogenital schistosomiasis estimated at about 1%. The parasite load of urine samples contaminated with Schistosoma haematobium was eliminated after 45 days of sanitation. Ecological sanitation is an alternative method of fertilization that has no impact on the prevalence of urogenital schistosomiasis. It could contribute to better control of this disease in endemic areas by breaking the transmission cycle of this disease. An agronomic study aimed at finding applicable doses of this fertilizer as well as fertilization strategies and application techniques should be considered for its rational use in each rice crop cycle. The sanitary impact of urine use on soil and crop products should also be verified, despite the hygienization provisions.

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AUTHORS' CONTRIBUTIONS

Author 1: Manuscript writing, study design and coordination
Author 2: Review of the article
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Figure 1: Map showing study sites [11].