EFFECTS OF HYGIENIZED URINE AND FAECES ON THE PREVALENCE OF ENDEMIC BILHARZIASIS: CASES OF TWO VILLAGES OF BOUAFLE IN THE IVORY COAST

Effets de l'urine et feces hygienises sur la prevalence des bilharziose endemiques: cas de deux villages de Bouaflé en Côte d'Ivoire

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KEY WORDS
Bilharziasis, Productive Sanitation, Blanfa, North Diacohou, Côte d'Ivoire.

Received 04 Nov. 2018
Accepted 26 Dec 2018
On line 31 Dec. 2018

Abstract Bilharziasis is a disease linked to poor hygiene and sanitation, which is a major public health problem in Côte d'Ivoire, particularly in the sanitary district of Bouaflé. In addition to chemotherapy, productive sanitation could be an effective means of controlling this disease. The objective of the study was to determine the effects of productive sanitation on the prevalence of schistosomiasis in Blanfla and North Diacohou, two villages in the sanitary district of Bouaflé where the disease is endemic. Pre-project (June-July 2014) and post-project (June-July 2016) prevalence surveys were conducted in Blanfla and North Diacohou. The urinary filtration and Kato-Kartz techniques were used for screening bilharzia in a sample of 100 people selected from 100 households per village. The productive sanitation project was carried out only in Blanfla during the two years. Before the project, the respective prevalence rates of urinary and intestinal schistosomiasis were 16% and 27% in Blanfla; they were 14% and 19% in North Diacohou. In Blanfla, during the productive sanitation project, 442.60 m³ of urine and 198.24 tonnes of faeces produced and hygienized for agriculture significantly reduced defecation and urination in the open air. After the project, the respective prevalence rates of urinary and intestinal schistosomiasis were 5%; 7% in Blanfla; they were 10% and 16% in North Diacohou. There was a significant difference in prevalence of urinary (P = 0.011) and intestinal (P < 0.001) schistosomiasis in Blanfla after the productive sanitation project. Productive sanitation can be popularized as a means of controlling schistosomiasis and increasing crop yield.
MOTS CLES
Bilharzioses,
Assainissement productif,
Blanfa, Diacohou Nord,
Côte d’Ivoire.

Résumé
La bilharziose est une maladie liée au manque d’hygiène et
d’assainissement, et constitue un problème majeur de santé publique en Côte
d’Ivoire, particulièrement dans le district sanitaire de Bouaflé. Outre la
chimiothérapie, l’assainissement productif pourrait être un moyen efficace de
lutte contre cette maladie. L’objectif de cette étude était de déterminer les effets
de l’assainissement productif sur la prévalence des bilharzioses à Blanfla et
Diacohou nord, deux villages du district sanitaire de Bouaflé, où cette maladie est
endémique. Des études de prévalence, avant-projet (juin-juillet 2014) et après
projet (juin-juillet 2016), ont été réalisées à Blanfla et Diacohou Nord. Les
techniques de filtration urinaire et de Kato-Kartz ont été utilisées pour le
dépistage des bilharzioses sur un échantillon de 100 personnes sélectionnées
dans 100 ménages par villages. Le projet d’assainissement productif était réalisé
uniquement à Blanfla durant les deux années. Diacohou Nord a été choisi comme
village témoin. Avant le projet, les prévalences des bilharzioses urinaire et
intestinale à Blanfla étaient respectivement de 16% et 27%, elles étaient de 14%
et 19% à Diacohou Nord. Durant le projet d’assainissement productif à Blanfla,
442,60 m³ d’urine et 198,24 tonnes de fèces produites et hygiénisées pour
l’agriculture ont réduit significativement la défécation et la miction à l’air libre.
Après le projet, les prévalences des bilharzioses urinaire et intestinale étaient
respectivement de 5% et 7% à Blanfla; elles étaient de 10% et 16% à Diacohou
Nord. Une différence significative de prévalence des bilharzioses urinaire
(P = 0,011) et intestinale (P < 0,001) a été observée à Blanfla, après le projet
d’assainissement productif. L’assainissement productif peut être vulgarisé
comme un moyen de lutte contre les bilharzioses et permettre d’augmenter le
rendement agricole.

1. Introduction
Bilharziasis is an infectious tropical disease that mainly
occurs in Africa, Asia and South America [1]. Overall, it
affects 74 countries and is experiencing a resurgence with
the discovery of new outbreaks despite new treatments
and control measures [2]. Of the estimated 800 million
people at risk of infection, more than 200 million are
parasitized and more than 20 million are suffering from a
severe and disabling form, with an estimated mortality
rate of nearly 200,000 people per year [3-4].
Schistosomiasis has major health and socio-economic
repercussions in developing countries, where it
constitutes a major public health problem [5]. The fight
against schistosomiasis is based on the use of
molluscicides, mass treatment with medicines, waterways
management, health education, drinking water supply
and improvement of sanitation services [6-7]. In order
to make the administration of pest control visible, sanitation
work and a population education program must be
undertaken beforehand [8]. Access to drinking water and
hygiene is also important in the control of schistosomiasis,
which is currently largely based on preventive
chemotherapy with Praziquantel [9].

However, despite the widespread, combined or isolated
use of conventional sanitation that emphasizes
sensitization and rejection of human excreta with other
control methods, outbreaks of schistosomiasis persist in
some localities [10-12]. It is therefore important to take
another look at the use of human excreta in order to put
an end to open defecation and urination and to break the
infectious cycle of this pathology. This goal can be
achieved through productive sanitation which through
behavioral change combines autonomous sanitation and
agronomic aspects. This approach requires improved
sanitation facilities with an adequate management system
that is useful for rural development and encourages the
development of excreta as fertilizer [13].

The benefits of Ecosan are the protection of the
environment, health, water table, the improvement of the
soil fertility, the increase of the agricultural production,
the improvement of the producer’s income and the
improvement of food security [14]. In addition, the
Marahoué region of central western Côte d’Ivoire is
considered as the second area with endemic
schistosomiasis in the country, with a prevalence rate of
10% to 20% [15-16].
In this region, good sanitation practices remain basic with more than 74% of the population practicing open defecation [17]. In addition, the Marahoué region has a dense hydrographic network with the Bandama River and numerous intermittent streams [18]. All these environmental factors favor the emergence and continuance of water-borne diseases such as schistosomiasis and make this region an adequate area to initiate productive sanitation as a potential efficient intervention. We thus evaluated the effects of such intervention on schistosomiasis in Bouaflé, one of the largest site of schistosomiasis in Côte d'Ivoire. The objective of this study was to determine the effects of productive sanitation on the prevalence of schistosomiasis in Blanfla and North Diacohou, two villages in the health district of Bouaflé, where the disease is endemic.

2. Material and methods

2.1. Study zone

Located in the transition zone between dense forest and wooded savanna, in the center-west of Côte d'Ivoire, the sanitary district of Bouaflé includes five sub-prefectures with Bouaflé as chief administrative district (Cf. Fig. 1).

The climate in the sanitary district of Bouaflé is hot and humid and has two dry seasons (i.e., July to August and November to February) and two rainy seasons (i.e., March to June, September to October). The sanitary district is crossed by two main rivers that are the White Bandama in the East and the Red Bandama or Marahoué in the West which gave its name to the region [18]. Respective distances from the city of Bouaflé were 14 km to Blanfla, and 45 km to North Diacohou. The village of Blanfla is mainly watered by hydroagricultural dam built on a lake while that of North Diacohou is watered by a small dam and a river.

2.2 Population selection

The pre-project on schistosomiasis prevalence at Blanfla and North Diacohou took place between June 28 and July 13, 2014, the post-project between June 25 and 10 July 2016.

In the Pre-project, we included any person aged between 1 and 70 years, having resided in the villages of Blanfla or North Diacohou for at least 6 months before the project and who agreed to participate in the study.

In the post-project, were included in the study, all persons treated with Praziquantel during the mass treatment of the population and having resided in both villages throughout the duration of the project (July 2014 to July 2016). The mass treatment of the populations of the two villages took place between the 1st and the 31st of August 2014. The size of the sample rounded and increased by 10% was calculated with the method of systematic random sampling [20-21]:

\[ N = \frac{t^2 \cdot p (1-p)}{e^2} \] with \( t = 1.645 \) (90% confidence level); \( e = \) margin of error at 7%; \( p = \) prevalence at 20%, and this gave \( N = 100 \) households per village. A total of 200 households were surveyed in the two villages.

2.3 Collection of Stool and urine sampling for schistosomiasis screening

To collect stool and urine specimens in Blanfla and North Diacohou, a three-person team consisting of a community health worker, the principal investigator and a nurse was involved. Per village and in each selected household, two (02) jars of 60 ml each were given to a randomly selected participant to collect their urine and faeces. The jars were distributed the day before between 17h and 23h.

A participant was identified by their first and last name, an identification number (ID), their sex, their age and the name of their parents, and this avoided information bias. The ID and the name of the participant were marked on the jars.

Regarding urinary schistosomiasis, moderate physical exercise was requested from the participants (i.e., rapid walking or fast ascending 2 or 3 times a staircase) for the
collection of urine to promote the urination of eggs and improve the sensitivity of the examinations at laboratories [22]. For intestinal schistosomiasis, morning stools filling 3/4 of the pillbox were provided by the participants. The jars were recovered the next morning between 6 a.m and 10 a.m, at the health center of the village. The urine and stool samples were collected in two separate boxes and sent to the Central Laboratory of the Regional Hospital Center of Bouaflé.

2.4 Laboratory procedures for the detection of urinary and intestinal bilharziasis

Microscopic examination of urine was performed by urine filtration techniques [23]. A quantity of 10 ml of homogenized urine is taken using a 10cc plastic syringe and filtered on a 12μm membrane filter in one of the 13 mm diameter filter-holders. After removal, the membrane filter is immediately stained with lugol 5% prior to searching, observing and counting Schistosoma haematobium eggs at the x 40 objective of a microscope (Olympus CX 21). The parasite load is defined as the number of eggs per 10 ml [24].

Microscopic examination of stool was performed by the Kato-Kartz method for the identification of Schistosoma mansoni [25]. According to this method, cellophane papers of rectangular shape and dimensions of 3 cm × 2 cm are immersed in a solution containing 100 ml of glycerine, 100 ml of distilled water and 1 ml of methylene blue for 24 hours. About 41.7 g of collected stool are then spread on an object-carrying slide then covered with cellophane paper previously dipped in the previous solution. The preparation is inverted and then crushed over several layers of absorbent paper so as to spread it well. Finally, the slides are examined under an optical microscope after a lightening time of 30-45 minutes. The number of eggs per gram of fecal matter (pasty stool) is equal to the number of eggs observed x 24 before the correction due to the appearance of the saddle. If the stools are not pasty, the correction coefficients are x 0.5: for solid stool, x 1.5 for semi-liquid stools, and x 2 for liquid stool [26].

2.5 Productive sanitation

The longitudinal study of productive sanitation took place in the village of Blanfla in the period of July 2014 to November 2016. The construction of Dry Toilets with Urine Deviation (TSDU) concerned households that agreed to participate in the project.

The sample size of the TSDU to be constructed, was calculated by the following formula [21]:

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

with \( t = 1.645 \) (90% confidence level); \( e \) = margin of error at 7% \( p \) = proportion of toilets improved to 25%, and this gave \( N = 100 \) households.

The calculation of the improved latrine (TSDU) coverage rate in the village of Blanfla was defined by the following formula: \( p = \frac{(N)}{(Nt)} \times 100 \) with \( p \) = rate (%); \( N \) = number of households with TSDU; \( Nt \) = Total number of households.

2.5.1. Process of TSDU acquisition by households

Acquisition of TSDU is voluntary and subject to a contract of engagement (TSDU acquisition application form) with well-defined reimbursement schedules of credit for the construction of the TSDU, and within the Community Led Total Sanitation-Ecological Sanitation (CLTS-ECOSAN) approach. For CLTS, the tools developed by this methodology are: mapping, calculating dung, contamination routes, washing hands, calculating expenses related to faecal peril diseases, visiting sites of defecation, demonstration poop-food and poop-water, community decision-making to stop open defecation and the action plan to achieve this goal. When the community commits to ending open defecation, TSDU is offered as a credible alternative equipment to achieve the goal it is committed to. For this purpose, films and images on the fertilizing value of urine and faeces are rolled out and the TSDU is identified as a "fertilizer factory".

In addition, a microcredit mechanism for the acquisition of TSDU is offered to households. If the household finds this amount high, they are offered an alternative (form) to reduce the cost of the construction of the TSDU for which they must provide a certain number of local materials. In this way, the credit for construction can be reduced.

2.5.2. Construction of TSDU in households

As soon as the membership fee was paid, the participatory construction of TSDUs started. TSDU dimension (height width, depth) were 1.30 m x 1 m x2.30 m, with a pit whose dimension were 70 cm x 50 cm; 60 cm. This construction took place over the period from July 2014 to December 2014. The monitoring of the construction process was done through a sheet that shows the level of achievement of the various stages of construction including under Basement (implementation, wall Mounting, pit excavation, underpinning, plastering, support, bowl, anal cleaning, scree, vent pipe) and superstructure (Roofing, Cladding), finishing (Painting, Door, Drum, Can, Hand Washer) notified on the sheet. Each TSDU were georeferenced.

2.5.3. Use of TSDU in households

The correct use of TSDU is defined as the respect of 10 indicators including the low presence of odor, the low presence of flies, the absence of maggot, the absence faeces on the slab near the defecation hole, the correct entry of urine into the can, the lid on the defecation hole used, the presence of ash pot for the stool cover, stool coverage with ash after defecation, the presence of handwasher, soap or ash and water, and proper use of
the handwashing device. Concerned households were systematically trained on techniques for using TSDU after completion of construction. The monitoring of the good use of TSDU in households is done on average once a week (Day (D) 4, D11, D18, D25, D32, D39, D47).

The collection of data on the proper use of toilets is done using the sheets presenting the indicators of good use. Each household was followed for two months (December 2014 to February 2015) through one visit per week to ensure the proper use of the TSDU.

2.5.4. Urine and faeces production

Urine and faeces were produced from July 2014 to July 2016. During defecation, faeces and urine are collected separately in two containers in the toilet pit of 0.21 m³. The urine is diverted into cans with an average capacity of 20 liters. These were topped with funnel called “bidur” and deposited discreetly behind the houses or near the toilet to serve as urinal. The faeces fall into 60-liter drums. The user then covers the faeces with ash. The content obtained can reach a mass of 40 kg. The concerned farmers, equipped with hygiene protection equipment (i.e., gloves, muffler), transport the cans and the drums, via wheelbarrow, motorcycle or bicycle, to the fields of Theobroma cocoa to be hygienized.

For each household the amount of urine collected is estimated from the number of cans of average capacity of 20 liters filled with urine while the amount of faeces is estimated by the number of average mass of 40 kg collected after filling TSDU

2.5.5. Hygienization of urine and faeces

Household monitoring of urine and faeces hygienization was carried out over the period of August 2014 after the availability of bio-fertilizers with the first beneficiaries of the TSDU, until July 2016 at the rate of one visit per month by the monitoring agent.

The urine is hygienized by storing it in a hermetically sealed can for 45 days. At the end of the process of hygienization we obtain the fertilizer called “furturine”. In each household, the quantity of urine obtained after hygienization is evaluated by totaling the number of cans with average capacity of 20 liters filled with furture. The monitoring parameters for the hygienization of urine are the presence of funnel in the can, the presence of ampoule or other device to prevent the loss of nitrogen, the absence of urine around the funnel, the hermetic closure of the filled can, the storage of the can out of the sun, the date of filling and the date of use of the can to check the time of sanitation. Hygienization takes place at the household’s house or in the farms.

Hygienization of faeces is done in a 60 cm deep pit for 6 months [27-28]. The fertilizer obtained is called “fertifè” for faeces. On average, the amount of fertifè from a 60-liter drum of faeces is estimated at 20 kg. We thus determine the total amount of fertifè by multiplying the number of hygienized drums by the weight of 20 kg. Hygiene monitoring indicators are the depth of the pit, the presence of a support (plastic bag or banana leaf) in the pit to collect faeces and prevent the loss of compost, closing the pit with the earth, the date of burial of faeces and the date of use of faeces so as to respect the time of hygienization. Hygienization of faeces takes place in the farms for most households.

2.5.6. Application of "furturine" and "fertifè" as fertilizer on cocoa fields

Each farmer was trained in the application of “furturine” and “fertifè” to cocoa. “Furturine” is applied without dilution on a furrow with a radius of 0.5 to 1 meter around the cocoa tree while the “fertifè” is spread as compost in this radius. In general the applied dose is 1 to 2 liters of “furturine” and 1 to 2 kg of fertifè per cocoa tree, brought every month preferably during periods of rains before the flowering of the cocoa tree.

2.5.7. Measuring the health impact of productive sanitation on the prevalence of bilharziasis in Blanfla and North Diacohou

As cited previously, the village of Blanfla did benefit from the productive sanitation while North Diacohou did not. Thus, in this study, the adoption of productive sanitation is considered as an indicator of the change of prevalence of bilharziasis in such areas.

2.6 Data processing and analysis

Contextual data on prevalence of schistosomiasis concerned the presence or absence of egg in urine and faeces, the parasite load and the number of tablet. The data entry was done in Excel sheet and the processing of these data was done with the software Epi Info™ 7 (CDC. USA). The odds ratio (OR), the confidence interval (CI) were used to compare prevalence in the pre- and post-projects and between locations. The calculation of the inverse of the odds ratio made it possible to know the level of exposure. The tests were significant at the level of 5%. The Student’s test and the confidence interval (CI) were used to compare the average number of tablets.

Sanitation data included the duration of TSDU construction, the number and size of households, the total population of villages, the number of latrines before and after the project, the amount of sanitized urine and faeces. Data entry was done in Excel sheet and the processing of these data was done with SPSS 22.0. The correlation between the duration of reception and the duration of realization of the different levels of TSDU structures has been determined. The Student’s test and the confidence interval (CI) were used to compare the averages of the different variables that are urine
production in bidurs and TSDU, households, toilets, population. The Kruskal Wallis test was used to compare the average biofertilizer quantities produced by households during the 25 months of collection. The variation coefficient allowed us to assess the dispersion of the different variables.

The Friedmann test was used to compare the amounts of biofertilizer applied between the different periods. Linear regression with prevalence as a dependent variable was used to establish the mathematical model of prevalence estimation as a function of the sanitation rate. The significance level of 5% was considered for the different tests.

The analysis of the health impact measurement was done through a contingency table.

2.7 Ethics and informed consent

This study was approved by the National Committee of Ethics and Research of Côte d'Ivoire under the No. 74 / MSLS / CNER-dkn.

The various field surveys were carried out after the authorization of the Departmental Director of Health and the Director of the Regional Hospital Center of Bouaflé. Adult persons participated in the study with written informed consent. Children aged 5 to 15 years participated in the study after their consent and the informed consent of their parents. Participants were reassured that the names will remain anonymous and that all information collected in this study will remain strictly confidential. At the end of each survey we proceeded to the free treatment in Praziquantel of the populations of the surveyed villages.

3. Result and Discussion

3.1. Result

3.1.1. Construction of TSDU

The spatial distribution of the TSDU in Figure 2 shows that the TSDU were implanted throughout the village of Blanfla. A total of 100 households adhered to and acquired the TSDU, built over a six-month period.

![Fig. 2: Spatial distribution of TSDU in the village of Blanfla (August 2015)](source: Results of this work)
Statistical processing of construction data is shown in Table I. In terms of statistical treatment, the first 50 TSDU were made available to households two months after the beginning of construction (0-60 days) while the remaining toilets were delivered 6 months after the beginning of the works.

Achievement of the works in the village lasted 180 days or 6 months. The average duration of the works was estimated at 78 days, i.e., around 3 months.

There is a significant positive correlation between the reception duration of works and the duration of completion of basement and superstructures. This means that the reception of the works depends on the duration of realization of the various stages of construction of the TSDU. The standard deviation for each level of construction of the structures is practically identical (46.12 to 48.25), which means that the construction time was similar for the TSDUs.

Tab. 1: Rythm of realization and reception of Dry Toilets with Urine Deviaton (TSDU) as a function of time in the village of Blanfla (August 2015)

<table>
<thead>
<tr>
<th>Duration (days)</th>
<th>0-30</th>
<th>31-60</th>
<th>61-90</th>
<th>91-120</th>
<th>121-150</th>
<th>151-180</th>
<th>Average</th>
<th>S.D</th>
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<th>p value</th>
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<td>12</td>
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<td>6</td>
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<td>45.79</td>
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</tr>
<tr>
<td>Hand washer</td>
<td>29</td>
<td>25</td>
<td>11</td>
<td>16</td>
<td>13</td>
<td>6</td>
<td>70.08</td>
<td>48.25</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Reception</td>
<td>29</td>
<td>25</td>
<td>11</td>
<td>16</td>
<td>13</td>
<td>6</td>
<td>70.08</td>
<td>48.25</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*: Statistically Significant;  S.D: Standard deviation;  r: Pearson Correlation Coefficient

Source: Results of this work

3.1.2. Using TSDU

The results in Table II show that toilets are mostly well used by households. The correct use of TSDU is defined as the respect of all the 10 monitoring indicators. The monitoring of the good use of TSDU in households is done on average once a week (D4, D11, D18, D25, D32, D39, D47). During the first 4 follow-ups from D4 to D25, the good use of the TSDU evolves gradually in the households and after one month, from D32 to D47, almost all the households acquired the perfect control of the TSDU use. From D4 to D47, the correlation between the good use of TSDU and the time of use is significant (r = 0.886, p = 0.001). The correlation between indicators of good use of the TSDU and the follow-up time is also significant (p < 0.05), except for the indicators "correct entry of the urine in the can" and "presence of ash pot for poo cover "which was not significant (p> 0.05).
Tab. 2: Indicators for monitoring the correct use of the TSDU in Blanfla as a function of time (August 2015)

<table>
<thead>
<tr>
<th>Indicators</th>
<th>D4</th>
<th>D11</th>
<th>D18</th>
<th>D25</th>
<th>D32</th>
<th>D39</th>
<th>D47</th>
<th>r</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low odor</td>
<td>77</td>
<td>76</td>
<td>88</td>
<td>96</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0.916</td>
<td>[0.33 ; 0.99]</td>
<td>0.004*</td>
</tr>
<tr>
<td>Low presence of flies</td>
<td>78</td>
<td>76</td>
<td>88</td>
<td>94</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0.926</td>
<td>[0.35 ; 0.95]</td>
<td>0.003*</td>
</tr>
<tr>
<td>Absence of maggot</td>
<td>79</td>
<td>77</td>
<td>89</td>
<td>95</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0.919</td>
<td>[0.31 ; 0.92]</td>
<td>0.003*</td>
</tr>
<tr>
<td>Absence of faeces on slab around defecation hole</td>
<td>98</td>
<td>99</td>
<td>99</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0.863</td>
<td>[0.02 ; 0.08]</td>
<td>0.012*</td>
</tr>
<tr>
<td>Correct entry of urine into the can</td>
<td>78</td>
<td>95</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0.680</td>
<td>[-0.09 ; 0.84]</td>
<td>0.093</td>
</tr>
<tr>
<td>Lid on the defecation hole used</td>
<td>80</td>
<td>89</td>
<td>96</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0.830</td>
<td>[0.10 ; 0.77]</td>
<td>0.021*</td>
</tr>
<tr>
<td>Presence ash pot for poo cover</td>
<td>100</td>
<td>98</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0.362</td>
<td>[-0.11 ; 0.22]</td>
<td>0.425*</td>
</tr>
<tr>
<td>Stool cover with ash after defecation</td>
<td>80</td>
<td>89</td>
<td>94</td>
<td>95</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0.920</td>
<td>[0.25 ; 0.71]</td>
<td>0.003*</td>
</tr>
<tr>
<td>Presence hand washer with soap or ash and water</td>
<td>79</td>
<td>82</td>
<td>88</td>
<td>96</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0.935</td>
<td>[0.33 ; 0.83]</td>
<td>0.002*</td>
</tr>
<tr>
<td>Good use hand wash device</td>
<td>75</td>
<td>77</td>
<td>86</td>
<td>94</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0.801</td>
<td>[0.21 ; 2.70]</td>
<td>0.030*</td>
</tr>
<tr>
<td>Conclusion Good Use TSDU</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Results of this work
*
*: Statistically Significant ; D : Day ; r: Pearson correlation coefficient ; 95% CI : 95% confidence interval ; TSDU : Dry Toilets with Urine Deviation

3.1.3. Production of biofertilizers

According to Table III, the duration of use of TSDU by households varied between 18 and 25 months since the completion of construction. The quantities of urine produced in bidur (CV = 45.4%), TSDU (CV = 46.4%) and faeces quantities (CV = 49.8%) were heterogeneous as all Cvs > 15%. However, the frequency of production of biofertilizers in bidur (CV = 9%), TSDU (CV = 7.4%) and drums (CV = 12.7%) was homogeneous.

From the 18th to the 25th month, the total quantity of urine produced in the bidur (195.51 m³) and the TSDU (247.09 m³) was 442.60 m³. The quantity of urine produced in the TSDU was significantly higher than that produced in the bidurs (p = 0.001). But in the different periods, the difference between the total quantities of urine produced in the bidur and the TSDU was not significant (χ² = 2.44, p = 0.487). The highest amount of urine produced in the Bidurs (68.45 m³) and TSDU (84.29 m³) were between the 22nd and the 23rd month.

For faeces, the total amount produced by households in the TSDU from the 18th to the 25th month was 198.24 tonnes. The highest amount of faeces is 64.68 tonnes and is between the 22nd and 23rd months. The amount of faeces produced in TSDU increases with the number of households using TSDU, but the difference between the quantities of faeces produced in the different periods was not significant (χ² = 3,272, p = 0.352).

For fertifè, the total amount produced by households in the TSDU from the 18th to the 25th month was 99.12 tonnes. The highest amount of fertifè was 32.34 tonnes produced between the 22nd and the 23rd months. The amount of fertifè produced in TSDU increases with the number of households using TSDU, but the difference between the amounts of fertifè produced in the different periods was not significant (χ² = 3.272, p = 0.352).
Tab. 3: Urine and fertifè production in the village of Blanfla (August 2015)

<table>
<thead>
<tr>
<th>Production</th>
<th>Duration (Days)</th>
<th>550 - 600</th>
<th>600 - 650</th>
<th>650 - 700</th>
<th>700 - 750</th>
<th>Total</th>
<th>Average</th>
<th>CV</th>
<th>t</th>
<th>( \chi^2 )</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Duration (Months)</td>
<td>18-20</td>
<td>20-22</td>
<td>22-23</td>
<td>23-25</td>
<td></td>
<td>0.10</td>
<td>1</td>
<td>0</td>
<td></td>
<td>0.485</td>
</tr>
<tr>
<td>Households</td>
<td>16</td>
<td>24</td>
<td>34</td>
<td>26</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>People</td>
<td>86</td>
<td>138</td>
<td>175</td>
<td>140</td>
<td></td>
<td>539</td>
<td></td>
<td>5</td>
<td></td>
<td>0.485</td>
<td></td>
</tr>
<tr>
<td>BIDURS (urine cans)</td>
<td>Bidurs quantity (l)</td>
<td>26765</td>
<td>45905</td>
<td>68449,5</td>
<td>54395</td>
<td>195514,5</td>
<td>1955,15</td>
<td>0.454</td>
<td>3.02</td>
<td>0.389</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quantity / day (l/d)</td>
<td>46.29</td>
<td>73.66</td>
<td>100.33</td>
<td>76.79</td>
<td>273.45</td>
<td>2.73</td>
<td>0.453</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Frequency (l/d/people)</td>
<td>0.54</td>
<td>0.53</td>
<td>0.57</td>
<td>0.56</td>
<td>0.51</td>
<td>0.55</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSDU (urine)</td>
<td>TSDU quantity (l)</td>
<td>34975</td>
<td>60000</td>
<td>84285</td>
<td>67830</td>
<td>247090</td>
<td>2470.9</td>
<td>0.464</td>
<td>2.43</td>
<td>0.487</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quantity / day (l/j)</td>
<td>60.3</td>
<td>96.21</td>
<td>123.51</td>
<td>95.75</td>
<td>345.6</td>
<td>3.76</td>
<td>0.467</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Frequency (l / d / people)</td>
<td>0.7</td>
<td>0.7</td>
<td>0.71</td>
<td>0.68</td>
<td>0.64</td>
<td>0.69</td>
<td>0.074</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIDURS and TSDU (urine)</td>
<td>Quantity Bidurs and TSDU (l)</td>
<td>61740</td>
<td>105905</td>
<td>152734,5</td>
<td>122225</td>
<td>442604,5</td>
<td>4426.05</td>
<td>0.455</td>
<td>-3.54</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quantity / day (l / d)</td>
<td>106.59</td>
<td>169.87</td>
<td>223.84</td>
<td>172.55</td>
<td>619.02</td>
<td>61.9</td>
<td>0.456</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Frequency (l/d/people)</td>
<td>1.24</td>
<td>1.23</td>
<td>1.28</td>
<td>1.23</td>
<td>1.15</td>
<td>1.24</td>
<td>0.045</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household</td>
<td>16</td>
<td>24</td>
<td>32</td>
<td>28</td>
<td></td>
<td>100</td>
<td></td>
<td>1</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>People</td>
<td>86</td>
<td>138</td>
<td>166</td>
<td>149</td>
<td></td>
<td>539</td>
<td></td>
<td>5</td>
<td></td>
<td>2.61</td>
<td></td>
</tr>
<tr>
<td>drums</td>
<td>703</td>
<td>1182</td>
<td>1617</td>
<td>1454</td>
<td></td>
<td>4956</td>
<td></td>
<td>49.56</td>
<td></td>
<td>0.498</td>
<td></td>
</tr>
<tr>
<td>FAECES</td>
<td>Quantity of faeces (Kg)</td>
<td>28120</td>
<td>47280</td>
<td>64680</td>
<td>58160</td>
<td>198240</td>
<td>1982.4</td>
<td>0.498</td>
<td>3.27</td>
<td>0.352</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quantity faeces / day (kg / day)</td>
<td>48.81</td>
<td>75.89</td>
<td>94.98</td>
<td>82.32</td>
<td>277.65</td>
<td>3.02</td>
<td>0.505</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Faeces frequency (Kg/d / people)</td>
<td>0.57</td>
<td>0.55</td>
<td>0.57</td>
<td>0.55</td>
<td>0.52</td>
<td>0.56</td>
<td>0.127</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FERTIFE</td>
<td>Quantity of fertifè (Kg)</td>
<td>14060</td>
<td>23640</td>
<td>32340</td>
<td>29080</td>
<td>99120</td>
<td>991.2</td>
<td>0.498</td>
<td>3.27</td>
<td>0.352</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quantity of fertifè / day (kg / d)</td>
<td>24.41</td>
<td>37.95</td>
<td>47.49</td>
<td>41.16</td>
<td>138.83</td>
<td>1.39</td>
<td>0.505</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fertifè frequency (Kg/d / people)</td>
<td>0.29</td>
<td>0.28</td>
<td>0.29</td>
<td>0.28</td>
<td>0.26</td>
<td>0.28</td>
<td>0.127</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Results of this work

1: liters  / d: liters per day ; 1 / d / p: liter per day per person ; Kg: Kilogram ; Kg / d: Kilogram per day ; Kg / d / pers: Kilogram per day per person
TSDU: Dry Toilets with Urine Deviation / CV: coefficient of variation

*: Statistically significant
3.1.4. Characteristics of villages before and after the productive sanitation project

Table 4 shows the results of households, toilets and populations before and after project. Before the project, the average difference in population size between Blanfla and North Diacohou was significant (p = 0.003). However, the difference in average of households (p = 0.682), toilets (p = 0.126) and treated populations (p = 0.588) between Blanfla and North Diacohou were not significant (p> 0.05).

After the project, the average household difference in TSDU (p = 0.001), toilets (p = 0.001), Praziquantel tablets received (p = 0.001) and tablets used (p = 0.001) between Blanfla and North Diacohou was significant.

Tab. 4: Households, populations, toilets and mass treatment in Blanfla and North Diacohou before project (2014) and after project (2016)

<table>
<thead>
<tr>
<th></th>
<th>Total households</th>
<th>Households with toilets</th>
<th>Households with TSDU</th>
<th>Total population</th>
<th>Treated Population</th>
<th>Tablets Received</th>
<th>Tablets used</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE PROJECT</td>
<td>Blanfla</td>
<td>317 (100)</td>
<td>22 (6,94)</td>
<td>NA</td>
<td>1688 (100)</td>
<td>1007 (59,65)</td>
<td>3500 (100)</td>
</tr>
<tr>
<td></td>
<td>North Diacohou</td>
<td>323 (100)</td>
<td>16 (4,95)</td>
<td>NA</td>
<td>1974 (100)</td>
<td>993 (50,30)</td>
<td>3000 (100)</td>
</tr>
<tr>
<td>Total</td>
<td>640 (100)</td>
<td>38 (5,94)</td>
<td>NA</td>
<td>3662 (100)</td>
<td>1960 (53,52)</td>
<td>6500 (100)</td>
<td>5683,5 (87,44)</td>
</tr>
<tr>
<td>t</td>
<td>-0,41</td>
<td>1,56</td>
<td>NA</td>
<td>-2,95</td>
<td>0,542</td>
<td>10,61</td>
<td>12,78</td>
</tr>
<tr>
<td>95% CI</td>
<td>[-17,3 ; 11,3]</td>
<td>[-0,89 ; 6,89]</td>
<td>NA</td>
<td>[-1,31 ; -0,26]</td>
<td>[-18,3 ; 32,3]</td>
<td>[203,8 ; 296,1]</td>
<td>[0,50 ; 0,68]</td>
</tr>
<tr>
<td>p</td>
<td>0,682</td>
<td>0,126</td>
<td>NA</td>
<td>0,003*</td>
<td>0,588</td>
<td>0,001*</td>
<td>0,001*</td>
</tr>
<tr>
<td>AFTER PROJECT</td>
<td>Blanfla</td>
<td>NA</td>
<td>122 (38,49)</td>
<td>100 (31,54)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>North Diacohou</td>
<td>NA</td>
<td>16 (4,95)</td>
<td>0 (0,00)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Total</td>
<td>NA</td>
<td>138 (21,56)</td>
<td>100 (15,63)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>t</td>
<td>NA</td>
<td>5,97</td>
<td>17,4</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>95% CI</td>
<td>NA</td>
<td>[35,4 ; 70,5]</td>
<td>[44,7 ; 56,2]</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>p</td>
<td>NA</td>
<td>0,001*</td>
<td>0,001*</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

*: Statistically Significant ; NA: Not Applicable ; TSDU: Dry Toilet with Urination Deviation ; t: Student’s test ; 95% CI: 95% confidence interval

Source: Results of this work

3.1.5. Health impact of productive sanitation

Pre-project and post-project prevalence results for bilharziasis are shown in Table 5.

Urinary bilharziasis
In Blanfla, the difference in prevalence before and after project was significant (p = 0.001). Productive sanitation, which is the exposure factor for schistosomiasis, is a protective factor OR = 0.28 (0.10-0.79). The sanitation subjects present in Blanfla are 3.57 (1 / OR) times less risk of contracting urinary schistosomiasis. In North Diacohou, the difference in prevalence of bilharziasis before and after project was not significant (OR = 0.68 (0.29-1.62), p = 0.384)

Intestinal bilharziasis
In Blanfla, the difference in pre- and post-project prevalence was significant (OR = 0.20 (0.08-0.49), p = 0.001). Blanfla subjects were 5 times (1/OR) less exposed to intestinal schistosomiasis, while in North Diacohou, there was no significant difference (p = 0.577) in prevalence of intestinal bilharziasis before and after the project.

Bilharziasis co-infection
Table V shows that in Blanfla, the difference in pre- and post-project prevalence was significant (OR = 0.12 (0.01-0.95, p = 0.035).) Blanfla subjects were 8, 60 times less exposed to the co-infection of schistosomiasis after the project.

In North Diacohou, in the absence of the project, the difference in pre- and post-project prevalence was not significant (OR = 1.00 (0.14-7.24), p = 1.000).
Tab. 5: Prevalence of schistosomiasis in the villages of Blanfla and North Diacohou, pre-project (2014) and post-project (2016), the sanitary district of Bouaflé. Côte d'Ivoire

<table>
<thead>
<tr>
<th>BLANFLA (n=100)</th>
<th>NORTH DIACOHOU (n=100)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urinary bilharziasis</strong></td>
<td><strong>Intestinal bilharziasis</strong></td>
</tr>
<tr>
<td><strong>Before-Project (n,%)</strong></td>
<td><strong>After Project (n,%)</strong></td>
</tr>
<tr>
<td>16 (16)</td>
<td>5 (5)</td>
</tr>
<tr>
<td>27 (27)</td>
<td>7 (7)</td>
</tr>
<tr>
<td>8 (8)</td>
<td>1 (1)</td>
</tr>
</tbody>
</table>

Source: Results of this work

* : Statistically Significant

The mathematical model for estimating the prevalence of schistosomiasis of the form y = ax + b is presented in Figure 3. After the project, the Blanfla TSDU coverage rate was 31.55%. From the model, if this rate were raised to 45%, the prevalence of urinary and intestinal bilharziasis which was respectively 16% and 27% before the project would be zero. Considering the villages of Blanfla and North Diacoh homogeneous, that is having the same characteristics (population size, presence of streams, open defecation, etc ...), the prevalence of urinary and intestinal schistosomiasis which was respectively 14% and 19% before the project in North Diacohou would be zero if the productive sanitation was performed there at a rate of 40% far below the sanitation rate, which would cancel the prevalence of schistosomiasis in Blanfla.

Fig. 3 : Mathematical model for estimating the prevalence of urinary and intestinal bilharziasis according to the sanitation rate in Blanfla and North Diacohou (June 2016)

Source : Results of this work
3.2. Discussion

Bilharziasis is a disease that is present in all regions of Côte d’Ivoire in general and in the Marahoué region in particular [16], [29]. Our study has shown the effects of productive sanitation on reducing the prevalence of schistosomiasis through the construction of TSDU, their proper use, production and hygienization of excreta for reuse in agriculture.

The construction of the TSDU in the village of Blanfla has gone through two phases. The first phase which lasted 1 to 2 months was marked by a keen interest during the first months because of the curiosity of the first participant households to know the "fertilizer factories" and their design. These first households were available and the delivery of construction materials was done without delay in order to reassure the population as to the credibility of the project. On the other hand, during the second phase, which lasted 2 to 6 months, the TSDU basement building phase in the participating households took longer. This could be explained by the unavailability of the household for the construction of the TSDU pit or the unavailability of the building materials (support, basin) of the basement at the desired time. The correlation between the basement and the provision of TSDU to households and between the superstructure and the reception of structures is significant because there is no quite a long time between the provision of the TSDU and the completion of the superstructure and basement. As soon as this step is completed the household is quick to make use of its latrine. Our results are not identical to those of the Torodi pilot project in Niger where the construction of 100 TSDU was done over four years [30]. Also, previous study shows the low community participation in latrine construction in rural Senegal [31].

The good use of TSDU is evolving in households, and after one month, almost all households have acquired perfect control over the use of TSDU. The progressive evolution of the good use of the TSDU could be explained by the non-mastery of this new type of toilet by the households during the first month. But over time, households have become accustomed to TSDU. However, the two indicators "correct entry of urine in the can" and "presence of ash pot for "poo" coverage were not correlated with time because households had difficulty either to reposition the can of the latrine because of certain technical failures in the pit, or to get used to the daily use of the ash in the latrine. This weekly evolution of the control of the use of the TSDU shows the will of the households to adopt this type of fertilizer and make their living place clean. The use of toilets has also been analyzed by other authors such as [32] in Chad and [33] who showed the people's support for the use of Ecosan toilets. However, some technical difficulties are noted in the dimension of the TSDU considered "a little small" during its use and the positioning of the can of the pit by some households.

Urine production in TSDU is significantly higher than the one produced in the bidurs because households use more toilets than urinals in the village. The quantities of urine and faeces produced by households from the 18th to the 25th month are heterogeneous while their frequency of production is homogeneous. This could be explained by a similar per-day production of urine and faeces by person, averaging 1.26 liters per person per day for urine and 0.56 kg per person per day for faeces.

Thus, the production of urine and faeces during the two years increases with the number of people in a household. These results are lower than those of a previous study which found 396 m³ of urine per year on the rice fields of Lopé and Niannar in Katiola [34]. In addition, the frequency of production of urine and faeces is estimated at 1.5 liters per person per day and between 51 kg and 190 kg per person per year, respectively [35-37].

In this study, in Blanfla, the subjects were 3.57 times less likely to contract urinary schistosomiasis while in the absence of the project the subjects of North Diacohou were only 1.47 times less exposed to the disease. Regarding intestinal schistosomiasis before and after the project, the subjects of Blanfla were 5 times less exposed while those of North Diacohou were 1.23 times less exposed to the disease. For the co-infection of schistosomiasis, the prevalence drops significantly in Blanfla compared to North Diacohou. These results lead to the conclusion that productive sanitation is a protective factor against urinary and intestinal bilharziasis. These results could be explained by the good use of the TSDU which was coupled with a mass treatment of the population of the village of Blanfla before the sanitation project. This use of toilets and bidurs helped to collect 442.60 m³ of urine and 198.24 tonnes of faeces to use as biofertilizer in agriculture. This has significantly reduced open urination and defecation and the rejection of Schistosoma haematobium and Schistosoma mansoni eggs in the nature by people who may be re-infected. The people of the village of Blanfla understood via the project the dangers of open defecation and urination, as well as the advantages of reusing urine and faeces as fertilizer in agriculture. The populations have adopted a change in behavior with regard to excreta. In addition, chemotherapy and public awareness of the risks associated with poor hygiene and sanitation practices would contribute to the achievement of these results. In contrast, in North Diaochohou, in the absence of the project, the bad practices of urine rejection and open defecation remain because the number of toilets and their use practically do not exist. The population is still exposed to the same risks of contamination of bilharziasis. Transmitted in the nature,
S. haematobium and S. mansoni eggs reach surface water and the disease transmission cycle is still maintained. The low reduction in the prevalence of bilharziasis after the project in North Diacohou could be attributed to the mass treatment of the population two years ago. These results are consistent with [3, 12, 38-39] which explain that sanitation, and chemotherapy coupled with awareness raising and health education, contribute to effectively fight against schistosomiasis. In addition, [40-41] show that poor hygiene practices and open defecation maintain diseases such as schistosomiasis.

There is no significant difference between households treated populations and toilets in both communities prior to the project. This would mean that before the project, the two villages had roughly the same demographic and health characteristics. But after the project, there is a significant difference between existing toilets in both villages. On the basis of these results, the establishment of the mathematical model equation of the form \( y = ax + b \) shows that if the productive sanitation was performed at a rate of 40% and 45% respectively in North Diacohou and Blanfla, the prevalence of schistosomiasis would be zero. This result could be explained by a total adoption of productive sanitation by the populations which would lead to break the infectious cycle of the transmission of schistosomiasis, until the eradication of this pathology. The references [11, 42-43] also show that the cleansing of the living environment is a public health strategy to prevent and combat schistosomiasis. But this rate of sanitation could not be performed in Blanfla because despite the keen interest, part of the population had concerns about the use of excreta in agriculture and the proposed model of TSDU.

4. Conclusion

The CLTS-ECOSAN methodology has significantly reduced defecation and urination in the open. The acquisition of TSDU by the microcredit mechanism was voluntary. The construction of the TSDU lasted 6 months and the households acquired the control of the use and the maintenance of the TSDU within 2 months. In Blanfla, the production of hygienized 442.60 m³ of urine and 198.24 tonnes of faeces over two years was intended for agriculture. The combined effect of chemoprevention and sanitation has reduced the prevalence of urinary and intestinal bilharziasis by 16% to 5% and 27% to 7%, respectively.

In North Diacohou, chemoprevention alone reduced the prevalence of Schistosoma haematobium from 14% to 10% and that of Schistosoma mansoni from 19% to 16%. Productive sanitation is a protective factor against schistosomiasis and can be proposed as an effective strategy against schistosomiasis, which is a major public health problem in Côte d’Ivoire.

Acknowledgement

Funding: This work has been achieved thanks to the financial and material support of the Intergovernmental Pan-African Agency Water and Sanitation for Africa through the Sanitation Component of the Millenium Water and Sanitation Program (PHAM) FED / 2012 / 024-147, of the National Schistosomiasis Control Program, Geo Helminthiases and Lymphatic Filariasis and the Fèlix Houphouët Boigny University of Abidjan (Côte d’Ivoire)

We express our sincere gratitude to all those involved in carrying out this work for their frank collaboration. These thanks are addressed to:
- Dr. Djè Koffi Hyacinthe, Departmental Director of Health of Bouaflé;
- Dr. Kobenan Koffi Tchiré, Director of the Bouaflé Regional Hospital Center;
- Dr. Méité Abdoulaye, Director of the National Program for the Control of Schistosomiasis, Geo Helminthiasis and Lymphatic Filariasis;
- Mr. Effoussou Ettien Luc, Biologist Engineer, Head of the Central Laboratory of the Regional Hospital Center of Bouaflé;
- Mr. N’Doli Konan Honoré, State Graduate Nurse, Head of the Rural Health Center of Blanfla;
- Mr. Ouattara Zié, State Graduate Nurse, Head of the North Diacohou Rural Dispensary;
- To the populations of the villages of Blanfla and North Diacohou.

Competing interest: the authors have no competing interest to declare.

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