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Solar Urine Disinfection as solution to reduce storage time in an integrated AgroSanitation system

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Solar Urine Disinfection as solution to reduce storage time in an integrated AgroSanitation system.

Toward a better management of urine in poor rural context of Burkina Faso

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Abstract:
In sub-Saharan Africa, malnutrition and poor sanitation are closely linked and still represent serious public health issues. In addition both issues mainly affect women and young children, especially in rural areas. That's why subsistence agriculture and sanitation improvement in this part of the world are vital and need to be strengthened.
The study presents AgroSanitation, an onsite and integrated concept based on combination of sanitation access and subsistence food production in Sahel rural area. After presenting the general concept and its implementation in a typical Sahelian village of Burkina Faso, the paper will focus on urine collection and its treatment. The sanitary treatment of this bio fertilizer will be developed by presenting a simple and low cost process based on solar radiation.

Keywords: urine; faeces; compost; solar radiation; bacteria; parasites; health risk

INTRODUCTION

Subsistence agriculture is the only source of food provision for vulnerable people in sub-Saharan villages, especially those located in the Sahel band. Subsistence agriculture in rural Sahel band is completely dependent on rainy season (3-4 months/year) and productivity is very low due to poor soil and lack of chemical fertilizer using. Production is then recurrently not sufficient to bridge the gap of food demand between two harvest periods. So during this crucial interval, it is vital to provide water and fertilizers as essential inputs to sustain a small farming activity. However, conventional source of water as well as chemical fertilizers are respectively rare and too expensive for these poor farmers, so alternative sources of water and fertilizers must be find. Concerning alternative water, greywater have a promising potential. Coming mainly from showers, dishwashers, and hand washbasins, it is estimated at between 70 to 85 % of total wastewater generated, which represents an important source of water for small farming (Abu Ghunmi et al., 2010) . Concerning alternative source of fertilizers, an average person[1] excretes annually 2.8 kg of nitrogen (N), 0.45 kg of phosphorous (P) and approximately 1.3 kg of potassium (K) (Dagerskog and Bonzi, 2010). However, both urine and faeces are contaminated with pathogenic bacteria and parasites harmful for farmers and consumers (Chandran et al., 2009; Trang et al., 2007)

AgroSanitation concept

AgroSanitation is an onsite and integrated concept which consist of collecting and treating rural domestic sanitary products (i.e. greywater, urine, faeces) for a safe recycling in subsistence agriculture (Fig. 1) in rural context.
The concept is implementing as research project in a small village of about 500 inhabitants, situated near Ziniaré (50 km far from Ouagadougou, capital of Burkina Faso). Four pilot families were chose in the village. Each family received a composting toilet where faeces and urine are separately collected, a pilot process for greywater collection and treatment and urinal installed in shower rooms to complete urine collection. In addition, each family delimit a small space of about 20 m² near greywater treatment facility. Inside this space, families cultivate not eaten raw vegetables like eggplant or okra by reusing urine, compost and greywater respectively as bio fertilizers and irrigation water. This activity is mainly performed during dry season (8 – 9 months /year), even if bio fertilizers can also be used in rainy season to cultivate rain fed cereals like maize, sorghum etc.

[1] Study based on 10 countries in West Africa

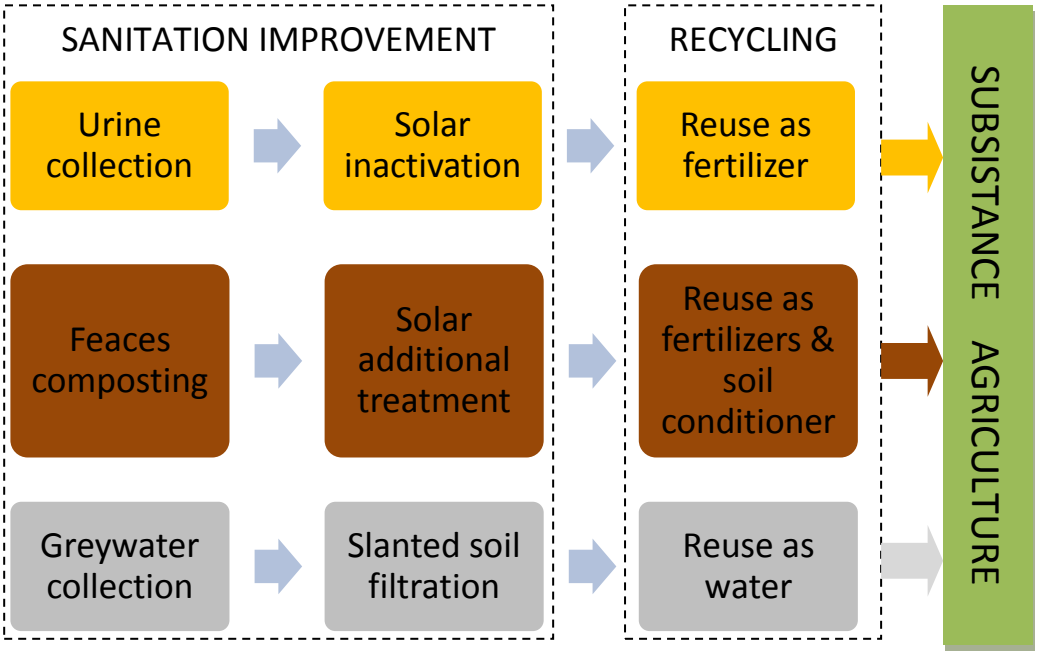

Figure 1: conceptual framework of AgroSanitation

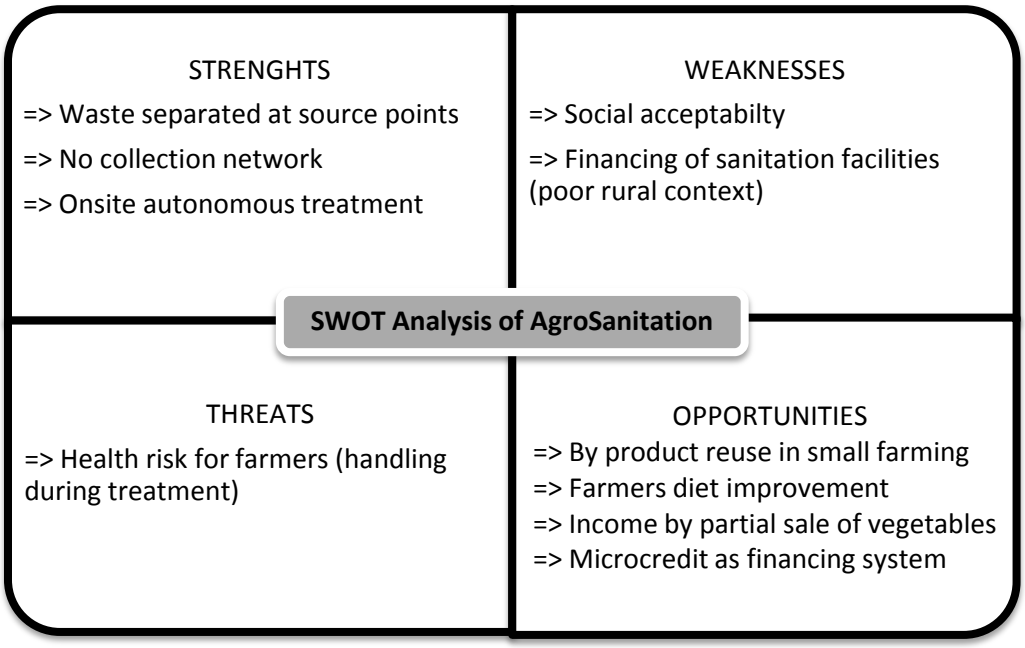

Figure 2: Strengths – Weaknesses – Opportunities –Threats of AgroSanitation system

Urine collection and treatment

They are at least 7 types of collection and treatment processes (Pronk and Koné, 2009; Maurer et al., 2006) but as indicated by authors, they are limited to one purpose like phosphorus or nitrogen recovery and major part of them are still at laboratory stage. In field implementation point of view, two processes can be considered: evaporation and storage. Evaporation, which mainly focuses on nutrients recovery optimization, is efficient but difficult to implement in rural context by farmers, due to handling risk and additional chemicals cost (Antonini et al., 2012). Storage is actually the most widespread process and aims to inactivate pathogen microorganisms. Also recognized as efficient to

remove major part of pathogens, its major constraint is however the large storage capacity required. Knowing that plastic tanks remains expensive item for poor rural population even to store drinking water, it is highly unlikely that those people could pay required numbers of tanks to store urine. Solar evaporation can help to reduce storage capacity demand provided that a rapid inactivation of pathogen is done prior to evaporation. Current literature recommendation for storage time varies from 1 to 6 months between 4 to 20°C (Winblad et al., 2004). However in sub-Saharan countries annual mean temperature is higher than 20°C meaning that recommended storage time could be reduced in these countries.

The present study aims to reduce storage time of urine treatment by applying Solar DISinfection (SODIS) method. Specific objectives were (1) identify exposition time based on temperature effect on bacteria inactivation (2) assess laboratory exposition time efficiency at field scale (3) assess temperature vs. temperature + UV radiation effect on bacteria inactivation. (4) Assess Escherichia coli efficiency as faecal indicator of Gram negative bacteria.

METHOD

SODIS treatment
SODIS is largely applied in developing countries for drinking water disinfection. It consists of filling water in transparent plastic bottle and expose it to the sun during 6 to 48 h (McGuigan et al., 2012). This treatment is known to inactivate several species of bacteria, fungi as well as ova and cysts of helminth and protozoa by additional effect of heating and UV radiation. Exposition time depend on temperature, turbidity and radiation intensity for drinking water (McGuigan et al., 2012; Gomez-Couso et al., 2009) and applying to urine disinfection, pH raising can be also taking into account as improving factor of microorganism inactivation since it already play important role in "simple storage" process.

Exposition time assessment based in temperature effect.
Sterilized urine (autoclaved at 121°C during 15 min) was used for the experiment. 500 ml of sterilized urine was inoculated with purified strain of Escherichia coli at reach about 6 $\log_{10}$ CFU/100 ml. This sample was divided in 10 parts of 50 ml each and 9 of them were stored at fixed temperature. The last one was used to check initial concentration of E. coli. The first 4 samples were tested every 30 min whereas the remaining 5 samples were tested every 1 hour to assess residual quantity of E.coli. The experiment was performed for 45°C and 50°C.

Field experiment
The field experiment was performed in 8 pilot families: 6 in rural area and 2 in semi urban area.

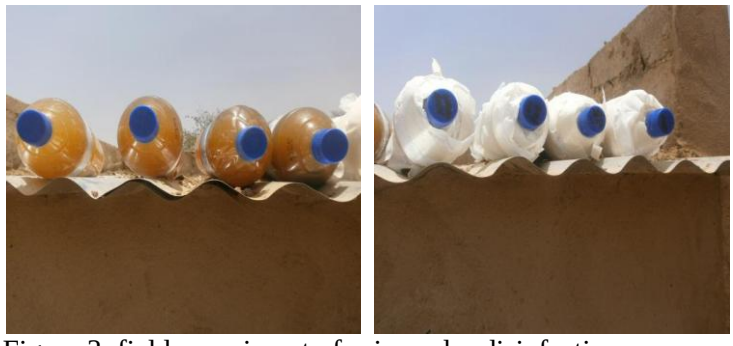
Figure 3: field experiment of urine solar disinfection

In each pilot family, 8 bottles of 1.5L filled with untreated urine were placed on a roof. As illustrated on figure 3, 4 bottles were covered with aluminium sheet to test only temperature effect on bacteria inactivation. As mentioned in table 1, experiment was performed 4 times in each site, except site 7 and 8 where only 2 tests were done. Each test was independent and the day of the test was randomly chosen during the hottest dry period of April – May. During this period, temperature raising was

estimated in 1.5 L bottled filled with urine and exposed to real sunlight from 8 am to 6 pm. Based on this simulation, the better exposition period was fixed between 10 am to 7 pm.

Table 1: Field experiments of SODIS test performed on 8 pilot families

	site 1	site 2	site 3	site 4	site 5	site 6	site 7	site 8	
16/04/2012	x	x	x	x					
19/04/2012					x	x			
23/04/2012					x	x			
24/04/2012							x	x	
26/04/2012	x	x	x	x					
30/04/2012	x	x	x	x					
03/05/2012					x	x			
07/05/2012	x	x	x	x					
09/05/2012					x	x	x		
15/05/2012								x	
Total/site	**4**	**4**	**4**	**4**	**4**	**4**	**2**	**2**	**28**

After exposition time (previously determined by laboratory experiment) all exposed bottled were stored at 4°C and transport at laboratory to be analysed immediately. Parameters analysed and related medium and analysis procedure are summarized in table 2.

Table 2: microbial analysis conditions

Parameter*	**medium**	**incubation time & temperature**
Escherichia coli	Chromocult coliform Agar	24H at 44.5°C
Salmonella sp	ChromAgar	48H at 37°C

*both parameters were analysed by spread plate technique

RESULTS AND DISCUSSION

Figure 4 represents laboratory simulation of temperature effect on E. coli inactivation. At 50°C total inactivation occur after 6 hours of exposition whereas after the same time only 50% of initial concentration was inactivated. Based on this result 6 hours of inactivation time was considered for field experiments.

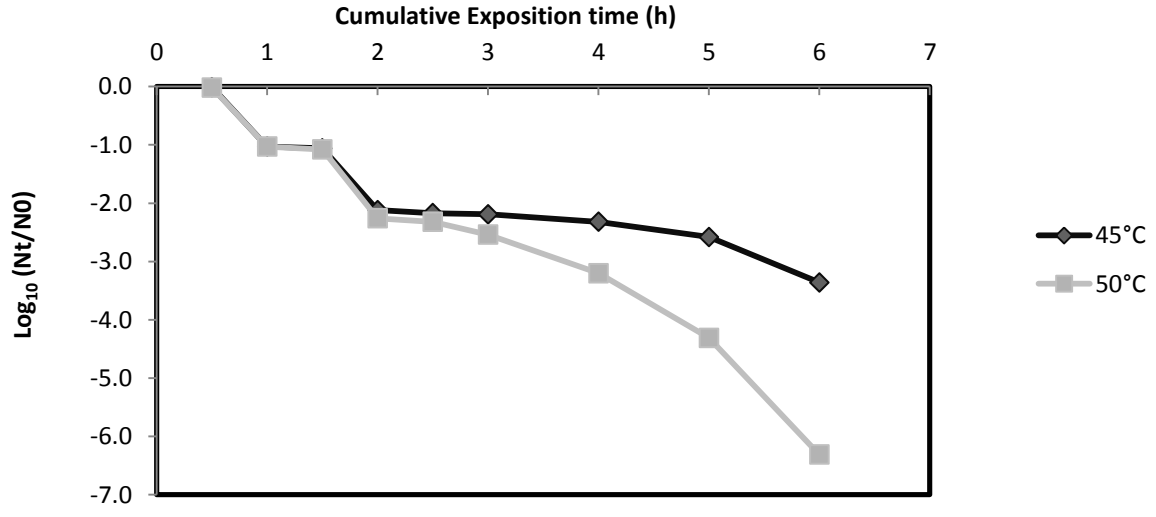

Figure 4: Inactivation kinetics of Escherichia coli during SODIS simulation at constant temperature

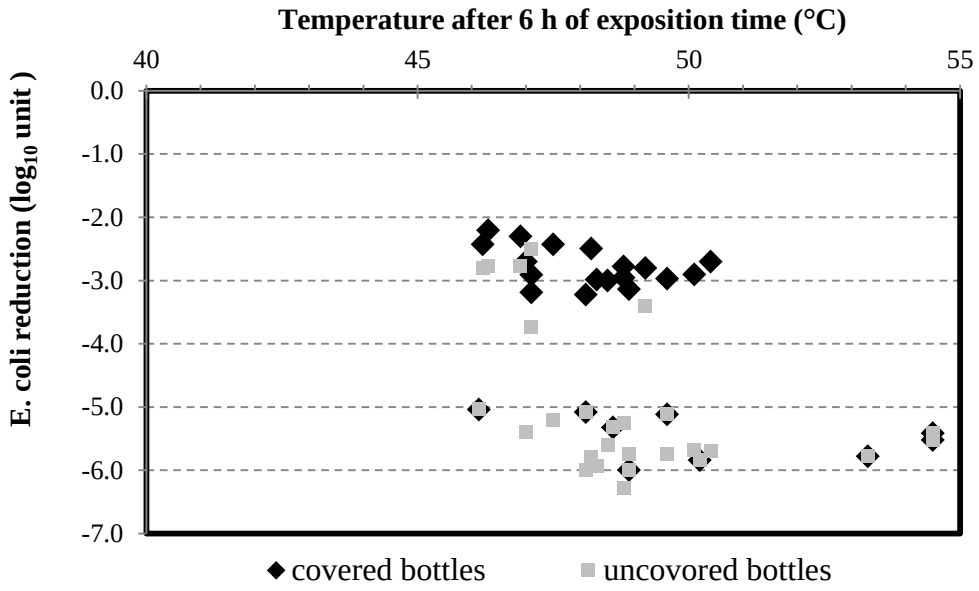

Figure 5: E. coli inactivation in urine by SODIS tested at field conditions

Result of E. coli inactivation, based on laboratory test conditions (i.e. 6 hours of inactivation time at 50°C with UV light radiation is presented on figure 5 (as covered bottles). The points represent the 28 SODIS tests performed in the different pilot families. Only 9 tests achieve a reduction unit > 5 Ulog, giving 28% of efficiency. Additional information on figure 6 gave mean temperature in urine bottles from 8 am to 6 pm (meseared during experiment period). This figure shows that 45 – 50 °C is reached inside the bottle for about 5 hours between 12 to 4.30 pm, meaning that laboratory conditions were not achieved during field test.

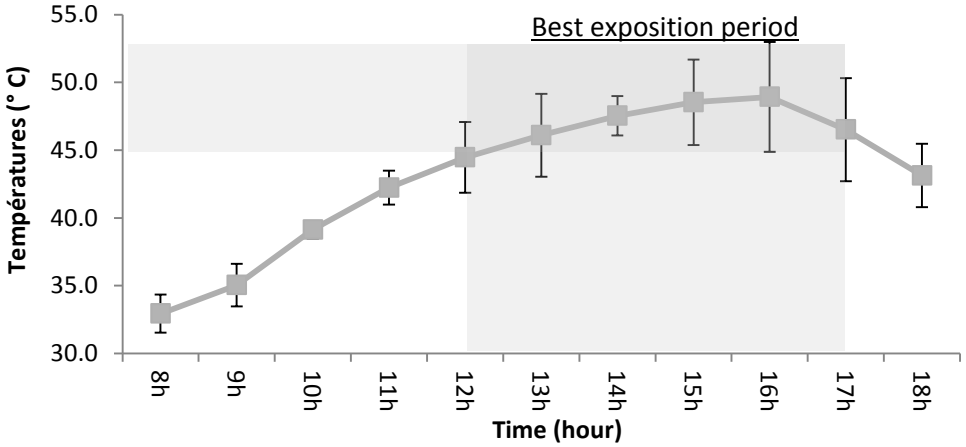

Figure 6: Temperature in 1.5L of urine bottle exposed to sunlight (mean of 3 days measurement)

However, tests performed with uncovered bottles (Figure 5) gave better results of inactivation. Such results represent combine effect of temperature + UV radiation increase inactivation efficiency at 79% (i.e. 22 tests with reduction unit > 5 Ulog).

The last figure 7 compares E. coli and Salmonella inactivation. When 79% of inactivation efficiency is reached for E. coli, in the same experimental condition, only 25% of efficient inactivation is observed for Salmonella. Such difference indicates that E. coli is not a good

fecal indicator, even for gram negative bacteria like Salmonella. This is in contradiction with WHO (2006).

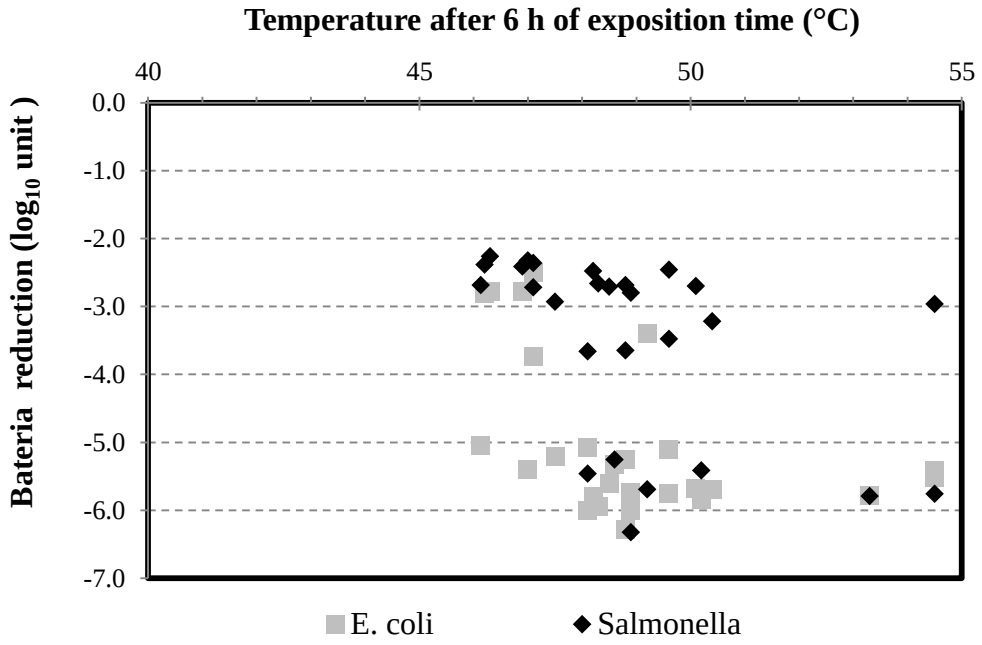

Figure 7: E.coli and Salmonella inactivation in urine by SODIS – field conditions - uncovered bottles

CONCLUSION

SODIS usually applied as microbial treatment for drinking water was tested in the present study to inactivate bacteria contained in urine. The results indicated that previous storage time (from 1 to 6 months) can be reduced to 5 hours with 79% of efficiency (percentage of bottles with at least -5 $\log_{10}$ unit of inactivation), provided a combined effect of temperature and UV radiation. The study also highlight that Escherichia coli was inappropriate as faecal indicator of Gram negative bacteria.

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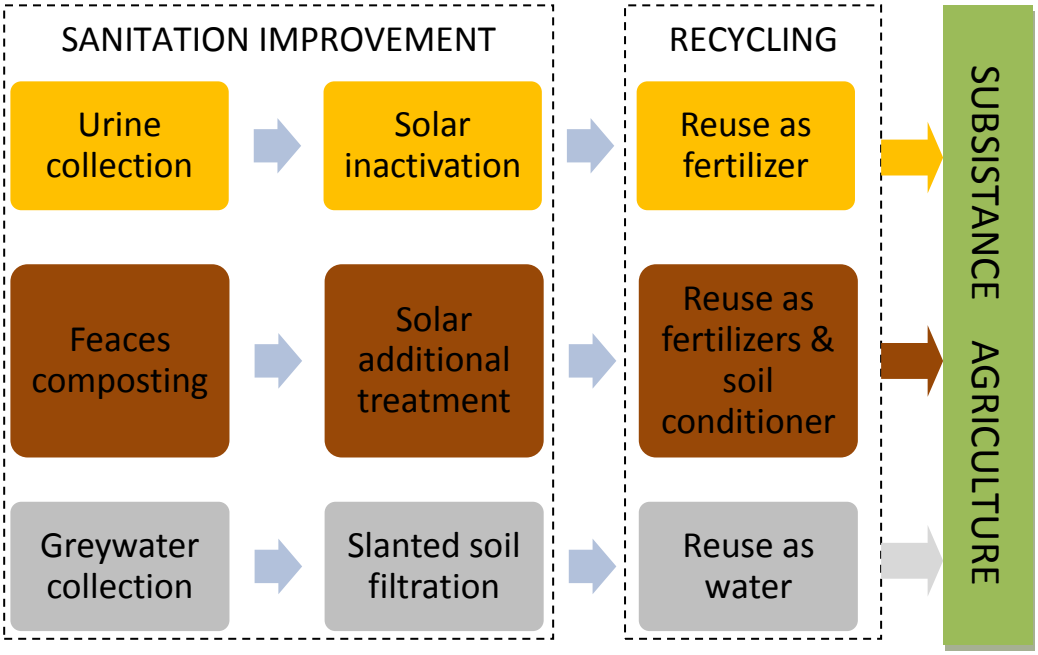
Figure



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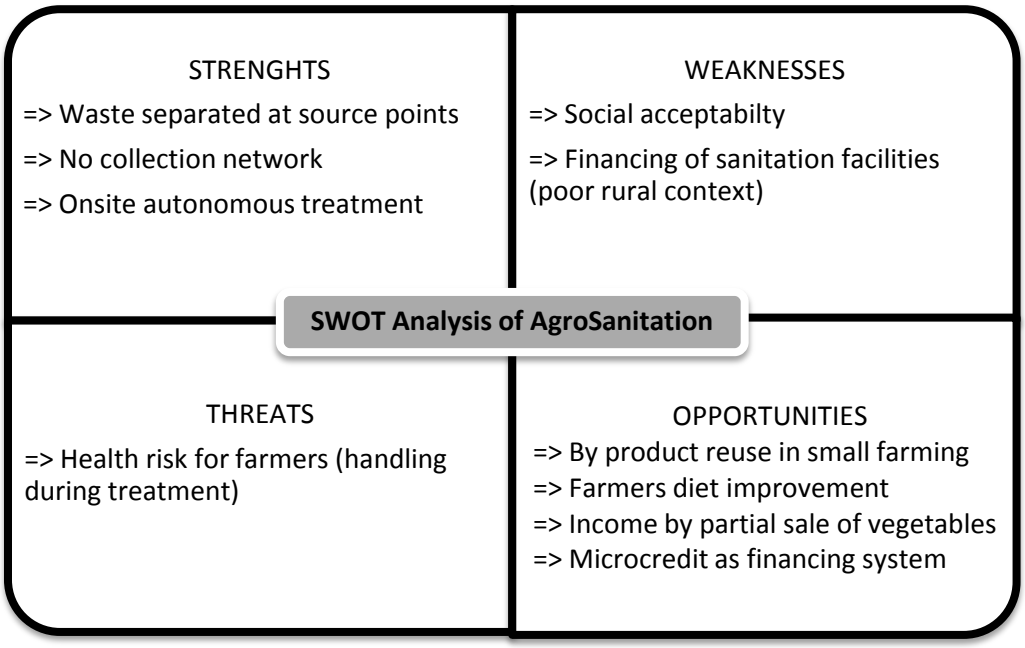

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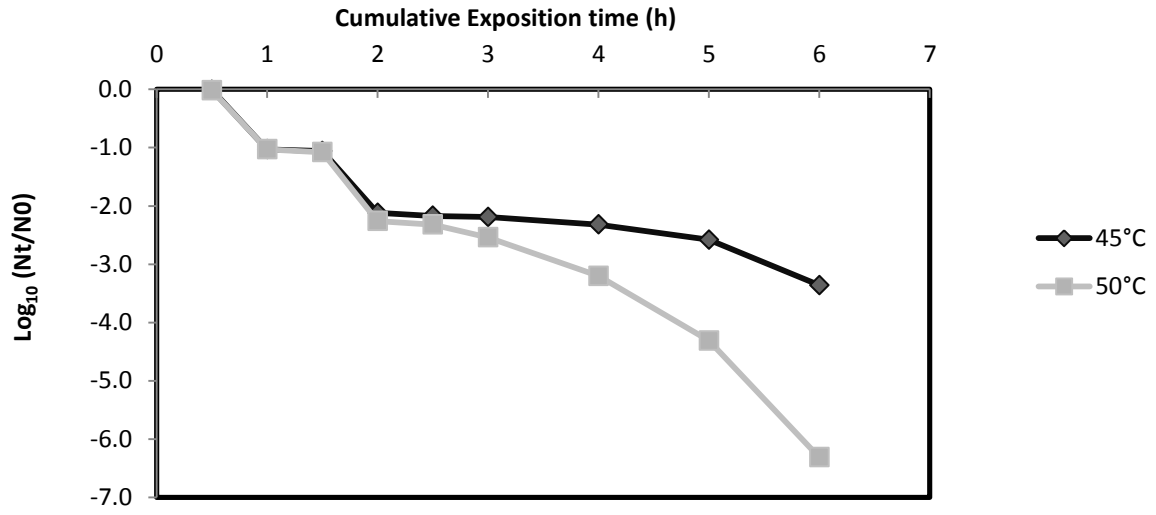
Figure 3: field experiment of urine solar disinfection



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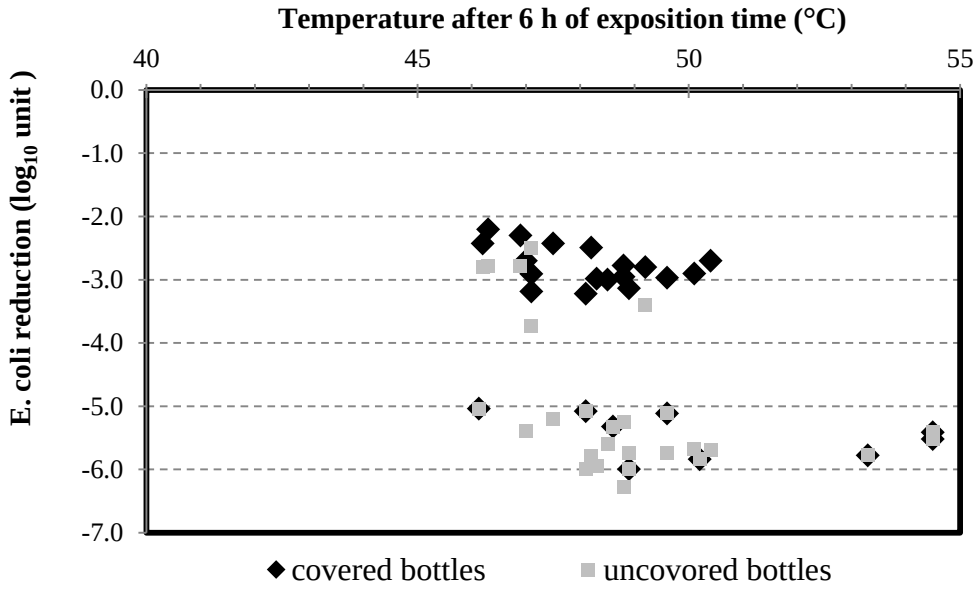

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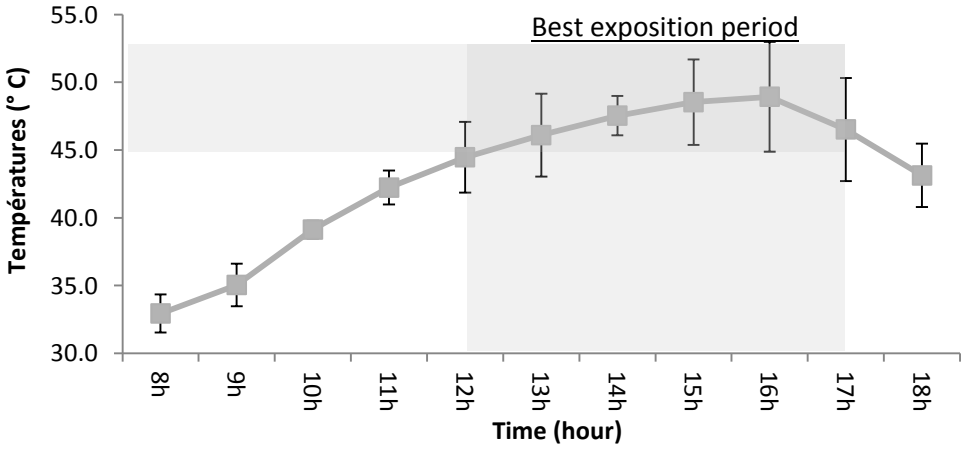

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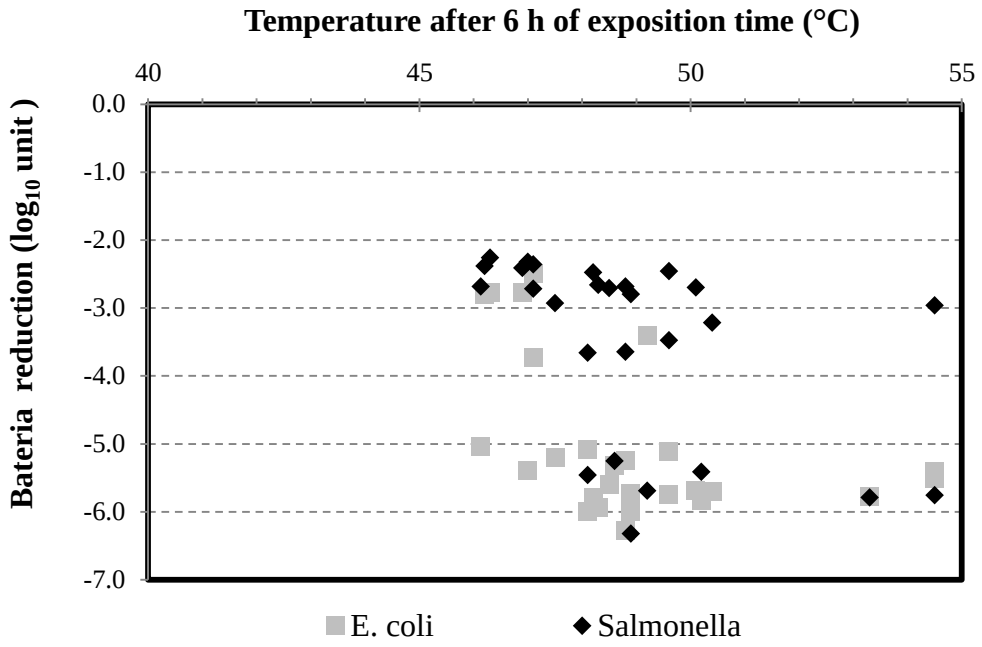

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