Caractérisation et évolution de la qualité microbiologique des eaux alternatives stockées au niveau d'un bâtiment–État de l'art et résultats d'expérimentations préliminaires

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Characterization and evolution of the microbiological quality of in-building stored alternative resource water -- literature review and results of preliminary experiments

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RÉSUMÉ

L'utilisation de ressources alternatives à l'eau potable suscite un intérêt croissant en France depuis déjà plusieurs années. Parmi ces ressources, deux plus particulièrement peuvent être produites et utilisées à l'échelle du bâtiment : l'eau de pluie en provenance des toitures et l'eau grise domestique, c'est-à-dire toutes les eaux usées domestiques à l'exception des eaux de vannes et généralement des eaux de cuisine. Pour être utilisées ces deux ressources doivent être préalablement stockées au sein du bâtiment. L'objectif de ce papier est de s'intéresser à la question de l'évolution de ces eaux stockées au fil du temps, en particulier en ce qui concerne leur qualité microbiologique. La première partie opère une revue de la littérature concernant l'évolution de la qualité de l'eau de pluie et des eaux grises brutes. La seconde partie présente deux expérimentations préliminaires qui ont été menées au sein du CSTB de Nantes. A partir de ces deux parties, une discussion est menée en troisième partie : elle vise à fournir des éléments à prendre en compte pour élaborer un cahier des charges permettant la mise en place d'une expérimentation comparative systématique de l'évolution de la qualité de ces eaux au sein du bâtiment expérimental AQUASIM.

ABSTRACT

The interest for using alternative resources to drinking water has been growing in France for several years. Among these resources, especially two can be produced and used at the building scale: roof-harvested rainwater (RHRW) and domestic greywater (DGW), namely all domestic wastewater excluding toilets wastes and water from kitchen sinks. These two kinds of water must be stored within the building before uses. This paper aims to address the issue of the evolution of the stored water over time, especially in regard to their microbiological quality. The first part performs a review of the literature on the evolution of stored RHRW and raw DGW quality. The second part presents two short preliminary experiments conducted within the CSTB Nantes. From these two parts, a discussion is conducted in order to provide elements to be taken into account for the specification of a systematic comparative experiment of the evolution of the quality of both waters within the experimental facility AQUASIM.

KEYWORDS

Greywater, Microbiology, Roof-Harvested rainwater, Water quality

1 INTRODUCTION

The interest for using alternative resources to drinking water is growing in France for several years due to the combination of several factors, especially new trends in the building industry stressing sustainable approaches and solutions, as shown in the example of roof harvested-rainwater (RHRW) (de Gouvello and Deutsch 2009). In the near future, domestic greywater (DGW) will probably be considered as another very promising technology for the building industry in France. Indeed, both technologies (RHRW and DGW) are *in situ* alternative resources, as they can be produced and stored on-site in the building for various durations. That is why it is be necessary to pay attention to the evolution of the stored water physicochemical and microbiological quality.

In France, RHRW for outdoor and indoor non-potable uses have been a significant topic in urbanized areas for more than 10 years. In 2008, a first national RHRW regulatory framework has been sketched (French decree of the August 21th 2008 on the harvesting rainwater and their use in and outside buildings), which defines several categories of usages of rainwater such as toilets flushing, ground washing and laundry washing (Nguyen-Deroche *et al.* 2011). However, there are no water quality standard or guidelines including the pertinent parameters that make it so difficult not only to evaluate the sanitary risk but also to define the technical requirement maintaining the harvested rainwater quality. In order to overcome this obstacle, it is necessary to gather data to assist in establishing water quality risk assessments (de Gouvello B. *et al.* 2012).

For worldwide practices, despite their potentials as water resource, the implementation of RHRW and DGW during the in-building water recycling has often been hampered because of perceptions of impaired water quality and associated health risks (Birks *et al.* 2004). Although greywater treatment and reuse are already used at real scale in water stressed areas such as Australia and Mediterranean countries but also in UK and Denmark (Hills *et al.* 2002; Birks *et al.* 2004; Muthukumaran *et al.* 2011), there is a lack of information on the occurrence and health risk from chemical and microbiological pollutants for both RHRW and raw DGW and a lack of appropriate guidelines that define the possible non-potable uses.

The main objectives of this study are to compare the microbiological quality of the stored RHRW and raw DGW by having a thorough literature review, to present the results of our preliminary experiments conducted on-site in CSTB (French Scientific and Technical Centre for Building) and to elaborate the experiments methodology which will allow us to characterize and monitor the microbiological quality of both alternative water resources.

2 LITERATURE REVIEW

With the development of the sustainable designed building, the study of in-building recycling alternative water resource has been a growing topic for the last decade. The quality issue of RHRW and DGW has gained more and more attention because of their potential to supplement and substitute existing drinking water supplies. However, there are very few articles comparing the physicochemical and microbiological quality of RHRW and DGW. Most studies often focus on only one type of water: RHRW (Lee *et al.* 2010; Farreny *et al.* 2011; Vialle *et al.* 2011) or DGW (Hernandez Leal *et al.* 2007; Smith and Bani-Melhem 2012). Some physicochemical parameters are analyzed for both kinds of water: temperature, pH, conductivity, color, turbidity, anions, cations, alkalinity, and total organic carbon. Additionally for DGW sample, the COD (chemical oxygen demand), BOD_5, total nitrogen and total phosphorus are most important parameters to monitor that reflect the nutrient level in the raw DGW samples.

Based on this fact, the following literature review has been divided into 2 parts, the RHRW and the raw DGW.

2.1 Roof harvested rainwater (RHRW)

Some scientific studies have suggested that the physicochemical quality of the RHRW meets local standard for ambient surface water but also meets their much stricter drinking water quality (Lye 2009). Conversely, some other studies come up with the fact that RHRW has shown a poor physicochemical quality (Vialle *et al.* 2011). The reason that may cause this inconsistence is the different experiment conditions in these researches.

By contrast, most of the studies find the microbiological quality of RHRW unacceptable. The fecal indicator load is often higher than the bathing water quality standard (Mendez *et al.* 2011;

Nguyen-Deroche *et al.* 2011; Vialle *et al.* 2011). Traditional microbiological quality is often assessed by the detection of indicators such as total coliforms (TC) and fecal coliforms (FC). However, Ahmed *et al.* (2011) have pointed out that one of the significant limitations of using fecal indicators to assess the microbial quality of water is their often-poor correlation with the presence of pathogenic bacteria, protozoa, and viruses. In addition, a variety of pathogens have been detected in different RHRW studies, such as *Campylobacter* sp., *Salmonella* sp., *Aeromonas* sp., *Legionella* sp. and *Giardia sp.* (Albrechtsen 2002; Birks *et al.* 2004; Schets *et al.* 2010).

The sample strategy that is applied most frequently is to take water sample right after the every rainfall event. There are a few researches that focus on the retention time of RHRW and the evolution of its physicochemical or microbiological quality in the storage tank even though it is essential information for the design and maintenance of RHRW catchment system. Lye (2009) has mentioned that well-designed catchment systems will have to address fit-for-purpose water qualities. The French decree in august 21th 2008 on harvesting rainwater and their uses in and outside buildings has also addressed the obligation of maintenance operations carried out by the owner of the system. The owner has to check every six months that the rainwater system is clean and has to clean the filter and to drain, clean and disinfect the storage every year (Nguyen-Deroche *et al.* 2011), but this recommendation is not based on the monitoring of physical, chemical and microbiological parameters.

For evolution of microbiological indicators during storage, one relevant research has been conducted by Schets *et al.* (2010), who have found out that the concentration of the microbial pathogen (in this case *Aeromonas hydrophila*) declined throughout time, it would be absent after certain days in storage systems.

2.2 Raw domestic greywater (DGW)

Characteristics of raw DGW vary from the nature of collected water (Li *et al.* 2009), the number of people in the household (Birks *et al.* 2004) and their living habits (Li *et al.* 2009).Generally speaking, the DGW can broadly be defined as all wastewater generated in the household, excluding toilet waste. The less contaminated DGW from bathroom sinks, baths and showers can be called 'light greywater and the more contaminated DGW from laundry, dishwashers and, in some instances, kitchen sinks can be called 'dark greywater'. (Birks and Hills 2007). While Kitchen greywater often contributes the highest level of organic substance, suspended solids, turbidity and nitrogen, the DGW from bathroom and laundry are considered the raw DGW of better value.

The COD/BOD_5 ratio is a pertinent indicator of biodegradability and helpful to select the best treatment technique as well as COD: N: P ratio. COD: N: P ratio of 100:20:1 is required for aerobic treatment and a ratio of 350:5:1 is required for anaerobic treatment (Hernández Leal *et al.* 2011). But with a COD/BOD_5 ratio close to 0.5, all types of raw DGW show good biodegradability (Li *et al.* 2009). Different reuse applications require different water quality specifications and thus different demand of treatments varying from single processes to more advanced one. To achieve this purpose, COD, BOD_5, total nitrogen (TN) and total phosphorus (TP) are the parameters to characterize raw DGW quality besides those parameters for RHRW.

Some data are available for physicochemical and microbiological quality of raw DGW. Revitt *et al.* (2011) showed that the quality of DGW (from bathroom) is characterized in the help of the parameters such as total organic carbon, BOD_5, COD and fecal and total coliforms. However, little information is known on loads and dynamics of micropollutants. Birks *et al.* (2004) focused on microbiological quality of DGW (from washbasin) by detecting indicators and pathogens. Considering the microbiological quality of raw DGW, the pollutant load is less than that of domestic sewage approximately from 1 to 2 orders of magnitude. But occurrence of fecal indicators bacteria in greywater estimated to 1.6×10^2 to 1.0×10^7 demonstrates the potential of presence of fecal transmitted pathogens. Moreover punctual presence of pathogen protozoa *Cryptosporidium* sp*.*, *Giardia* sp. and *Legionella pneumophila* 2-14 were detected in raw DGW samples. In another study, *Pseudomonas aeruginosa* and *Staphylococcus aureus* were detected in the raw DGW (from bathroom) samples which are the opportunistic pathogens that may pose a particular risk to vulnerable individuals in households with inadequately treatment and disinfection (Winward *et al.* 2008).

Dixon *et al.* (1999) have conducted an investigation on the evolution of stored raw DGW (from bath and laundry) and tried to develop a model for two very important chemical parameters: DO (dissolved oxygen) and COD. The results showed that storing raw DGW for 24 h may significantly improve water quality through rapid settlement of organic particles, however, storage beyond 48 h leads to deplete DO levels and potential comfort problems.

2.3 Conclusion of literature study

The previous study on characterization of both RHRW and DGW has reached an undisputed achievement. However, there is lack of information for the following aspects.

- The evolution over time of the RHRW and DGW quality in the storage tank have almost never been studied and it will be very interesting to monitor and compare the quality difference between these two kinds of water resources since they have the similar potential for non-potable uses (toilet flushing, garden irrigation etc.
- The detection of both indicator organisms and microbial pathogens allows us to verify their correlation and to give a complete assessment of microbiological quality of RHRW and DGW.
- The quality of both RHRW and DGW depends on numerous factors and to identify those factors that affect water quality will be supplementary information to our characterization of alternative water resources.

3 PRELIMINARY EXPERIMENTS

Preliminary experiments were conducted in order to define an appropriate sampling strategy, identify suitable analysis protocols adapted to RHRW and DGW monitoring, assess the possible range of the parameters and specify experimental conditions for a reliable long-term monitoring in the near future. Therefore the following results of our preliminary experiments will give a general idea of the physicochemical and microbiological quality of both stored RHRW and raw DGW.

The majority of this experiment (water collection, storage, sampling and analysis) was carried out in the experimental building dedicated to in-building water study: AQUASIM. This large building located in Nantes (France), aims to set up experimentations and full-scale simulations of the in-building water cycling system in controlled conditions. RHRW was also harvested from the rooftop of another experimental facility: Jules Verne wind tunnel. In this context, we have conducted two sets of experiments: one is for RHRW; the other is for raw DGW.

3.1 RHRW experiments

3.1.1 Experiment objectives

The objective of this preliminary study is to define the pertinent physicochemical and microbiological parameters and to figure out the most appropriate analytical protocols so as to conduct a 4-month monitoring of the evolution of the quality of stored RHRW within the AQUASIM. This experimental facility allowed us to implement this project in controlled conditions in order to characterize the RHRW.

3.1.2 Experiment description

Two separate RHRW sources were for our research. One part of RHRW was harvested in rooftop of AQUASIM. The material of this 250 m^2 rooftop was concrete and inclined at 2% degreed from the center roof. The harvested rainwater was then channeled by gravity through PVC-c pipes into a polypropylene storage tank of 5 m^3 from where the water sample could be withdrawn. The other part of RHRW was harvested from the 2000 m^2 rooftop of another experiment facility called Jules Verne wind tunnel. The material of this roof is galvanized steel mixed with carbon and iron, covered with a protective layer of zinc. Rain dripping on the roof was harvested by using three PVC gutters and then passed by a concrete inspection well. When the well was full, RHRW was directed through concrete pipes to a 200 m^3 storage basin outside. This outside basin was coated with an EPDM liner and covered with a tarpaulin. Before the study began, the conveying devices and water storage basin had been cleaned out and flushed.

The monitoring of physicochemical and microbiological quality lasted approximately 3 months from the April 15th to the July 10th 2012. For the record, since the current protocols for surface water analyses were not suitable for rainwater (especially the dilution of the raw water sample), the first samples were dedicated to find out the proper analysis protocol. The physicochemical parameters that monitored were: pH, temperature, conductivity, dissolved oxygen (DO), turbidity, total suspended solids (TSS) and total organic carbon (TOC). The microorganisms were selected for this study: Heterotrophic Plate Count (HPC), fecal indicators (total coliforms, *Escherichia* coli, *Enterococci*). Occurrence of some other bacteria including pathogens (spores of sulfite-reducing anaerobic bacteria, *Clostridium perfringens*, *Salmonella* sp. and *Campylobacter* sp.*)* was also studied punctually.

3.2 DGW experiment

3.2.1 *Experiment objectives*

This experiment was aimed to define the physicochemical and microbiological parameters to monitor the quality of stored raw DGW and their possible range. Through this short term (7-day) but intensive (4 set of sampling) experiment, the evolution of the raw DGW has been described in order to orientate the future long term monitoring.

3.2.2 *Experimental description*

Raw DGW used in this study came from showers and laundry in AQUASIM and were produced on a single day. Then they were channeled separately, through PVC-c pipes, into two dedicated 5 m^3 polypropylene storage tanks. When the expected volume was obtained, a mix of both types of DG W was realized in a 1m^3 polypropylene storage tank: (ratio shower water: washing machine is 2:1). This ratio is based on the realistic situation that simulates the daily water consumption in an ordinary family. Before every sampling, the agitator was launched in the tank and kept string for about 15 minutes that avoid the stratification effect.

One point to be clarified is that for preliminary study of DGW, the sample was withdrawn only for the mix DGW. The physicochemical and microbiological parameters in the mix DGW have been monitored during one week, immediately after mixing (T0), after 24h (T24), 72h (T72) and 7 days of storage. The physicochemical parameters are pH, temperature, conductivity, dissolved oxygen (DO), turbidity, total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD_5), total organic carbon (TOC) and Nitrogen as Ammonia (NH_4-N). The microorganisms studied were: Heterotrophic Plate Count (HP C), fecal indicator (total coliform, *Escherichia* coli, *enterococci,* and other microbial pathogens (*Pseudomonas aeruginosa*, total staphylococci, pathogenic *staphylococci*, *Salmonella* sp., *Campylobacter* sp., spores of sulfite-reducing anaerobes bacteria, spores of *Clostridium perfringens*, *Legionella* sp., *Legionella pneumophila*, F specific-RNA phages, mesophilic *Amoebae*, *Cryptosporidium sp.*, *Giardia sp.).* The results of our preliminary experiment are the most reliable reference for the selection of the detected pathogens of our future long-period monitoring.

3.3 Preliminary experiment results

3.3.1 *RHRW*

Table 1 shows the physicochemical properties of RHRW. Since there is no specific water quality standard for rainwater, we chose to compare our experimental data with the current French drinking water quality standards and European bathing water quality standards. Needless to say, the drinking water quality standards are stricter than the bathing water quality standards.

Table 1 The physicochemical properties of RHRW

	AQUASIM rooftop Mean value (range)	Jules Verne rooftop Mean value (range)	French Drinking water standards	European bathing water standard
PH	6.66 (6.35~7.03)	5.54 (5.22~6.12)	6.5~9	6~9
Conductivity (µS.cm^{-1})	98.1 (58.3~122.1)	34.84 (27.70~41.80)	⩾200 and ⩽1100	
Turbidity (NTU)	8.7 (5~20)	5.45 (2.00~14.00)	2	
TSS (mg.L^{-1})	8,19(1,4~43,6)	2.55 (0.20~15.80)		
TOC (ppm)	5.04(2.71~6.47)	2.71 (1.85~4.40)		

The average pH of RHRW from the AQUASIM rooftop was 6.66 (6.35-7.03); all the samples could be characterized as neutral and most of them met the both standards. In the other hand however, the pH of RHRW from Jules Verne wind tunnel rooftop (5.54; 5.22~6.12) was a little lower than both water standards and even can be characterized as weak acid. There were no standards for TSS of TOC, but with reasonable concentrations for water samples, these 2 parameters were characterized as suitable for non-potable uses.

In terms of the microbiological quality, figure 1 shows the levels of two fecal indicators *Escherichia* coli and *enterococci*. Overall, the fecal indicator load in RHRW from the AQUASIM rooftop was significantly higher than that of Jules Verne Wind tunnel rooftop. Contrary to the Jules Verne rooftop, AQUASIM rooftop is an accessible one where scientific equipment was installed involving huma n intervention. Moreover the storage ta nk is lo cated in the bui lding. This both parameters may influence the microbiological load over the course of the trial parallel experiment in AQUASIM during this experiment. The load of the *Escherichia* coli was higher than that of *Enterococci*. It should be highlighted that the European bathing water standards fix maximum concentration of *Escherichia coli* is to 900 cfu.mL^{-1} that is considered as sufficient quality of bathing water. All the RHRW samples meet this stand ard. However, the Europe an bathing wate r fixed the maximum concentration of *enterococci to 330* cfu.mL^{-1}as sufficient quality of bathing water while 2 samples in AQUASIM out of 4 (50%) were worse that this value and considered as poor quality.

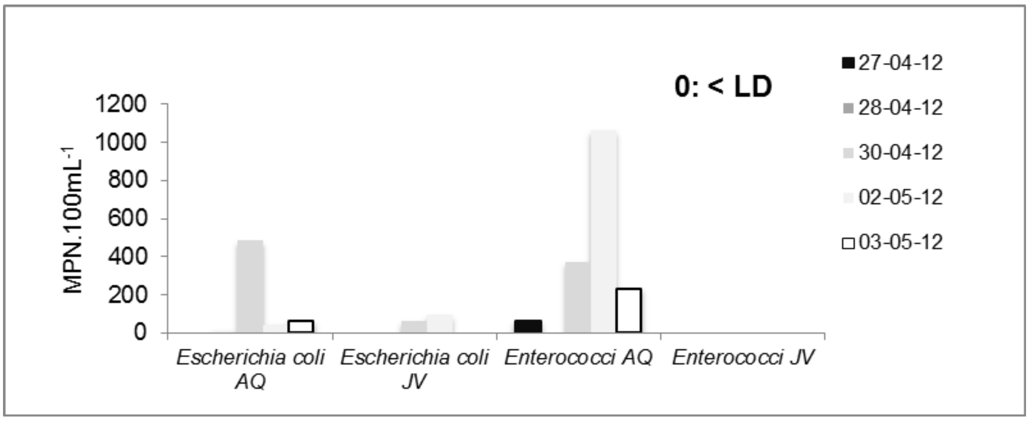

Figure 1: Evo lution of *Escherichia* coli and *enterococci* of RHRW (unit: MPN.100mL^{-1})

. **(AQ: RHRW from Aquasim rooftop; JV: RHRW from Jules Verne wind tunnel rooftop)**

In terms of the microbiological quality, figure 1 shows the levels of two fecal indicators *Escherichia* coli and *enterococci*. The unit e we use wa s MPN (Mo st probable n umber) per 100mL and v alue zero means the concentration of the fecal indicator is below the limit of detection. Overall, the fecal indicator load in RHRW from the AQUASIM rooftop was significantly higher than that of Jules Verne Wind tunnel rooftop. Contrary to the ro oftop of the Jules Verne ro oftop, the rooftop AQASIM is an accessible one where scientific equipment was installed involving human intervention. Moreover the storage tank is located in the building. This both parameters may influence the microbiological load over the course of the trial parallel experiment in AQUASIM during this experiment. The load of the *Escherichia* coli was higher than that of *enterococci,* which was consistent with their load in the biological cycle. It should be highlighted that the European bathing water standards fix maximum concentration of *Escherichia* coli is 900 cfu.mL^{-1} that is considered as sufficient quality of bathing water. The RHRW sample s in are all meet this standard. However, the Eu ropean bathing water fixed the maxi mum concentration of *enterococci to 330* cfu.mL^{-1}as sufficient quality of bathing water while 2 samples in AQUASIM out of 4 (50%) were worse that this value and considered as poor quality.

In May, pun ctually analyses showed the ab sence of spores of sulfite-reducing anaerobic bacteria, *Clostridium perfringens, Campylobacter* sp. and *Salmonella* sp. in RHRW fro m the Jules Verne wi nd tunnel rooftop. On the ot her hand, in RHRW f rom AQUASIM rooftop, *Clostridium perfringens and Salmonella* sp. were not d etected, but analyses showed the presence of *Campylobacter* sp. and the occurrence of spores of sulfite-reducing anaerobic bacteria at a concentration of 340 cfu.mL^{-1}.

3.3.2 DGW

Table 2 shows the results of raw DGW physicochemical quality and Figure 2 shows the results of raw DGW microbiological analyses. As we mentioned before, this monitoring has been conducted for exactly one week.

As we can observe in table 2, most parameters (pH, conductivity, TSS, turbidity, COD, TN, TP, NH_4^+) remain relatively stable during the monitoring period, while DO showed a fluctuating trend and BOD_5 declined over time. Figure 2 shows the evolution microbiological load in the stored raw DGW samples. The concentration of all microorganisms stayed fairly stable (all deficit s are within o ne order of magnitude) throughout the monitori ng period. The presence of total coliforms, *Escherichia* coli and *enterococci* prove the fecal contamination in raw DGW.

Table 2. The physicochemical properties of untreated DGW

Parameters	T=0	T=24 h	T=72h	T=7 days
pH	7.75	7.25	7.28	7.30
DO ($mg.L^{-1}$)	3.40	5.91	4.74	3.36
Conductivity ($\mu S.cm^{-1}$)	576	585	572	571
TSS ($mg.L^{-1}$)	42	44	31	29
Turbidity (NTU)	46	33	30	27
COD (mgO_2 L^{-1})	173	141	163	149
BOD_5 (mgO_2 L^{-1})	60	50	40	40
TN ($mg.L^{-1}$)	18.60	20.62	20.41	21.19
TP ($mg.L^{-1}$)	1.3	1.3	1.2	1.3
NH_4^+($mgN.L^{-1}$)	10.8	13.9	11.7	11.1

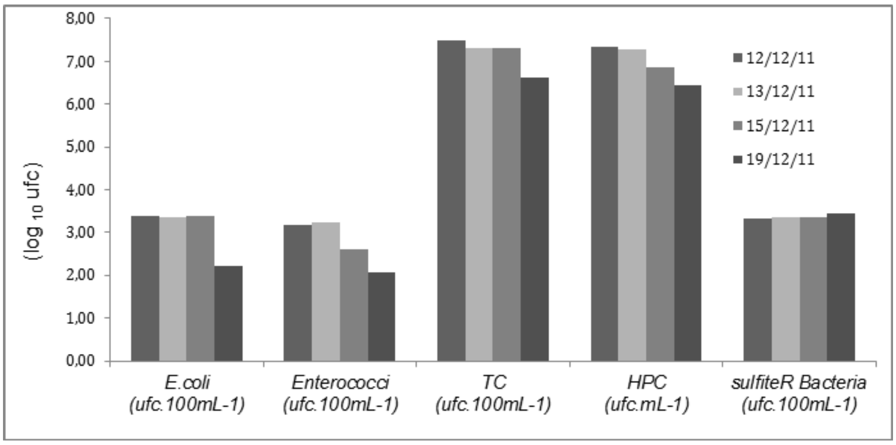

Figure 2. Evolution of microbiological parameters in stored raw DGW

In terms of microbial pathogens, Salmonella sp., *Campylobacter* sp., *Giardia sp*. and F specific-RNA phages were not detected in all analyze d samples. There were also no positive counts for *Legionella* sp., *Legionella pneumophila, Pseudomonas aeruginosa,* total staphylo cocci and pathogenic *staphylococci but that was* due to the background microflora so that the d etection limit was poor. *Cryptosporidium* sp. and *Clostridium perfringens* were only detected in the first analysis (T=0).

3.4 Discussion

The results of the preliminary experiments are reliable references for the future long-term experiment design in order to achieve its objectives: characterization and evolution of the microbiological quality of RHRW and DGW. These results allow us to defi ne the expe riment condition with sele ction of parameters and indicators, sampling strategy and experiment condition, which are the most important issues that should be taken into account.

3.4.1 Selection of parameters and indicators

Based on the results, the selection of physicochemical parameters will remain the same so that not only can we characterize the quality of RHRW and DGW, but also focus on the correlation between the their physicochemical and microbiological properties by designing the proper scenarios. Concerning the microbiological quality of RHRW and raw DGW, the selection of parameters were defined as below: the fecal indicator will be the same for both water sample: *Escherichia* coli and *Enterococci. Conversely, the selection of microbial pathogens will be different: for RHRW, the analysis of* spores of sulfite-reducing anaerobes, *Salmonella* sp., *Campylobacter* sp. and *Pseudomonas aeruginosa* will be carried out; for raw DGW, the pat hogens to detect will be spores of sulfite-reducing anaerobes, *Pseudomonas aeruginosa and* total staphylococci. Furthermore analysis of biofilm will be carried out because it can help the microorganism survive longer in the environment by protecting and supporting themselves (Simmons *et al.* 2008; Schets *et al.* 2010). The biofilm will be used as an indi cator for the stability of the eco-system in the storage system.

3.4.2 Sampling strategy

We can also define the sampling strategy for the future study according to the preliminary result：For raw DGW, the volume of the wate r source will be relatively stable overtime, so the sampling will be collected for a shorter periods but more frequently. On the other hand, the volume of produced RHRW and the weather condition vary overtime so that t he quality of RHRW will be monitored for 18 month including all the seasons.

3.4.3 Experiment condition

In order to ensure the reliability of our rainwater quality analysis, there is a small-scale weather station in the CSTB-Nantes site with package of equipment allowing us to monitor in-situ weather information: rainfall intensities, temperature, relative humidity, wind speed, wind direction, etc. All these factors may have significant influence on the microbiologic quality of the RHRW (Evans *et al.* 2006; Schets *et al.* 2010). Moreover, we will take pure rainwater sample as a control group. Furthermore, this would also allow us to identify the major weather factor that affect the quality of RHRW. The weather data should be fully recorded in order to help to explain the evolution of RHRW quality in the storage tank and that will also help us to define the weather patterns in CSTB site.

4 CONCLUSION AND PERSPECTIVES

The preliminary study of chara cterization of the RWRW and raw DG W was conducted in the experiment site in CSTB-Nantes. This experiment gave a general idea of RHRW and raw DGW quality that the presence of fecal microorganism contamination and the occurrence of microbial pathogens in both water samples. Both of them are not suitable for potable uses without treatment. Nevertheless, the definitive conclusion will be come up after the future long-term experiment

The preliminary result can also be useful to define the future long-term experiment specification. Some options have been identified: firstl y, the weather conditions will be fully recorded du ring whole experiment period. Secondly, pure rainwater will be also added to our sample and its microbiological quality will be also monitored. Last but not least, all these additional information will allow us to use the multivariate analysis tool (such as principal component analysis (PCA) and cluster analysis (CA)) to analyze the correlation between these factors and the RHRW quality.

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