Perception of rainwater harvesting in public buildings: Comparison between two case studies in France and in Brazil

Perception de l'utilisation de l'eau de pluie dans les bâtiments publics. Comparaison entre deux études de cas en France et au Brésil

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RÉSUMÉ

Cet article compare l'acceptabilité sociale de l'utilisation de l'eau de pluie dans deux bâtiments collectifs, l'un à vocation universitaire localisé en région parisienne, l'autre à vocation sportive situé dans la ville brésilienne de Belo Horizonte. Cet article propose d'évaluer les différences entre les deux cas en ce qui concerne l'utilisation de l'eau potable et sa substitution par de l'eau de pluie pour certains usages. L'analyse montre des différences en termes de perception en fonction du contexte socio-économique, du sexe et de la profession. Les usagers brésiliens se méfient davantage de la qualité de l'eau délivrée par le robinet et ont une perception plus pessimiste que les usagers français de la pluie. Les usagers masculins brésiliens sont plus ouverts au risque, 25% étant disposés à envisager l'eau de pluie même pour la boisson. En France, il n'existe pas de différence de perception entre hommes et femmes, mais le personnel administratif a une perception plus positive de la pluie que les chercheurs. Les résultats montrent, dans la perception des usagers, un lien entre usage et qualité de l'eau attendue pour l'eau de pluie, les usagers brésiliens attribuant une qualité supérieure à l'eau de pluie que les usagers français.

ABSTRACT

This article compares the acceptability of rainwater harvesting and use in two collective buildings, one of them in the region of Paris used for higher education and the other in the Brazilian city of Belo Horizonte used for sport education. The article proposes an evaluation of the differences between both locations in current water uses, the uses proposed for rainwater and the perception of tap water and rain water. The analysis shows differences of perception depending on socio-economic context, sex and professional occupation. On one hand the Brazilian users mistrust much more the quality of tap water and have more pessimistic perception of the “rain” than French people. On the other hand Brazilian users accepts rain water for more domestic usages than French ones, with 25% of male users even accepting it for drinking. In France the administrative personnel have more positive perception of rain than the research and development personnel, but, contrary to Brazil, no difference was detected between male and female users. The overall results indicate a probable link between the perceived quality required for a given household use, showing a positive correlation between the use and required acceptable water quality. In addition, Brazilian users perceived rain water as being of better quality than did French users.

KEYWORDS

Rainwater harvesting and use, water use, perception, water quality, buildings, France, Brazil

1 INTRODUCTION

One of the most pressing issues facing the world today is the conservation and preservation of natural resources. Population increase and technical progress, leading to intensified urban development and agriculture, generate important pollutant fluxes contributing to a greater imbalance between supply and demand of water of good quality. Hence management of existing water resources has become a priority issue for authorities worldwide.

Roofs represent an important percentage of the large impermeable areas covered by cities, offering an important potential for rainwater collection. Rainwater can replace an important part of the indoor uses like toilet flushing and cleaning (Ghisi et al 2006). Whilst rainwater harvesting (RWH) can provide a reliable source of water, it is generally ignored by policy in many countries (UNEP, 2009).

Most of the northern Europe countries have abundant water resources, so the need for extra supply is not a priority. In these cases rainwater harvesting should be considered as an alternative technology for flood control and natural resource preservation. This situation is different in the southern countries, especially in developing countries, where the additional water resource may help diminish the impact of periods of drought and help to face the Millennium Development Goals and the constraints of climate change (WWAP, 2006).

One of the major constraints for large scale rainwater harvesting and more in general water reuse, is the lack of relevant regulation and public acceptance (Angelakis et al 2003, De Gouvello 2007). In some European countries, regulatory frameworks and/or normalization standards have been developed in the past years. Normalization standards have been published in Germany in 2002 (DIN-1989) and in 2009 in United Kingdom (BS 8515). In France, a specific Decree (Arrêté du 21 août 2008) was adopted in summer 2008, opening the possibility of using rainwater inside the buildings for selected purposes like toilets flushing (De Gouvello et al., 2009). In Brazil the ABNT norm gave in 2007 a framework for non-drinking uses (ABNT 2007), though the biggest Brazilian rainwater harvesting program, the P1MC, set up to supply water to 5 million people, was already running (ABCMAC, 2009).

Managing the demand for water requires knowledge not only in how people use water, but also in the relationships between social and technical aspects of water use. By understanding the effects of these factors, water-management authorities will be in a better position to identify the conventional and non conventional uses and their characteristics, as well bring into line the needs of the final users more effectively. In some cases in Australia and in the Netherlands, the user community can show resistance to use of recycled water leading to abandonment of the project. This resistance seems to be related to a number of institutional factors and in particular to how well the community was prepared and consulted (McKay et al, 2003, Ryan et al. 2009). Greater understanding of these social factors in a policy context will facilitate adequate management of such schemes.

This study investigates the uses and perception of water in two public buildings, one in France and one in Brazil, where rainwater harvesting systems are proposed. The objective was to identify whether the different socio-economic contexts and the different type of uses have an impact on the perception of rainwater harvesting and the potential rainwater use and to draw lessons about the design and public consultation for rainwater harvesting projects.

2 METHODOLOGY

The metropolitan region of Paris (France) has about 11.7 million of habitants with densities varying from 20 000 habitants /km² in the center of Paris to less than 100 in the outskirts. The Human Development Index (HDI) of France is 0.961 (UNDP 2009) but can vary in the metropolitan region (Nascimento 2005). The average rainfall in Paris is 730 mm/year distributed over the whole year with a minimum in July and a maximum in April. The building is situated in the metropolitan region of Paris at Champs-sur-Marne, with a total constructed surface of 8000 m², hosting two engineering schools: ENPC for civil engineers and ENSG for geosciences engineers. The objective of rainwater harvesting is research, pedagogy and sustainable development.

Belo Horizonte is the third largest city of Brazil, with 2.5 million of inhabitants and mean population density of 7290 habitants /km². The HDI of Brazil is 0.813 (UNDP 2009) and varies within the city borders of Belo Horizonte from the level of northern Europe countries in the center, to the equivalent of countries in Africa in the shanty towns in peripheries (PNUD 2009). The average rainfall in Belo Horizonte is about 1500 mm/year concentrated in the hot rain season between October and March. The building is situated in the center of Belo Horizonte, has a global constructed surface of 400 m² and

was built for indoor climbing. The harvesting objective is water economy and sustainable development. Table 1 below, summaries the most important characteristics of both buildings.

Figure 1: Photos of the buildings of ENPC (left) and Rokaz (right), showing the main space and its scale

The buildings (figure 1) have comparable rainwater harvesting potential of about 4 m3/year/person. Therefore both systems have the possibility to reduce substantially their tap water use by adopting rainwater harvesting and rainwater use. Nevertheless the effective set-up will depend on investment, public authority acceptance and the user acceptance. The sampled populations are both, groups with high level education, probably closer to average high tech buildings users, rather than to cross-section of the community.

To evaluate the acceptance, the perception of future (end) users of RWH system was measured through a short questionnaire of 16 questions (2 more for Brazil due to specific situation). The questionnaire was distributed in France by mail and collected through Internet by “Google Docs”. In Brazil it was distributed in paper form to the trainees at their entry and collected at their exit.

The questions where divided in 3 categories: personal information such as age and educational background, uses made of water inside the building and rainwater harvesting perceptions. In both cases the question here preceded by small paragraph explaining the objectives of the project. The questions were “single” or “multiple” choice, with a response not being obligatory.

Description	**ENPC, Champs-sur-Marne, France,**	**Rokaz, Belo Horizonte Brazil,**
Function of the building	School for engineering, R&D	School for climbing
Harvesting purpose	Research, reuse in toilets	Water economy, reuse in toilets and possibly after treatment for showers
Type of construction	Recent, concrete, 5 floors, (20m high), vertical water distribution, constructed surface of 7900m²	Recent, concrete, 1 floor, (15m high), horizontal water distribution, constructed surface of 400m²
Occupation (openings hours)	8 AM – 10 PM	7 AM – 10 PM
Population (number of users)	1500	160
Daily frequentation	80%	40%
Mean water consumption	42 m3/d	1 m3/d
Principal water use	toilets (60 % of total)	toilets (90 % of total)

Table 1: General characteristics of the research objects

The questions were formulated in French and translated to Brazilian Portuguese by local staff in the way to produce the same questioning in the local social context, for example:

Question	France: What does rainwater suggest for you / Brazil: What is the first thing you think of, in relation to rainwater /
Answer	France: inconvenience – catastrophe –a gift of nature / Brazil: umbrella – flooding – rainwater harvesting

The responses were collected over one week and treated with spreadsheets programs Open Office 3.0 and Microsoft Office 2003.

As there does not exist any specific water quality parameter such as turbidity or pathogens to define exactly a water quality according to each specific household use (table 2), we propose to introduce the notion of "acceptable working distance" for each use. This distance represents the risk accepted and indirectly a perceived water quality.

Different researches about distance and risk perception like those of Maderthaner (1978) and Stone (2001) in US for nuclear power plants or Seidl et al. (2008) in Brazil for detention ponds suggest that an average person will keep (health) risk factors at distance, the higher will be the risk, the bigger will be the distance to the risk factor. Redefining this postulate for water (re)use, a user will accept do a lot with clean in comparison to dirty water. Or at the distance of for example 10 centimeters, he will accept to do hand cleaning but not the cleaning of toilets. So there exist an unconscious relation between the level of risk (use of water of given quality) and the distance to the risk factor even for household water application. Marks et al. (2008) defines this phenomena in his research with reclaimed water as "ladder of acceptability" given by the risk of direct contact with recycled water being more important in hand use than if it would be used in / through a machine. In our case the acceptable working distance would be a synonym of water quality and could be attributed to rain water by the user population in the form of selected household water use.

The working distance was defined as the distance between the human body and the effective place of action, if executed manually. Action means in this context use of household water like brushing of teeth, washing dishes or cleaning floor. For example drinking has no distance, dish washing is about 30 centimeters, floor cleaning has a distance of 1 meter etc. The "working distance" is an individual data, specific for each person and should be properly defined in field through measurements. Rough estimation is proposed in table 2. To contextualize these values, the levels of French norms for drinking and swimming water quality are also given.

Water use	Working distance	Working distance (cm)	NTU //E.Coli (/100ml)
Drinking	none	0 – 1	1 // 0*
Food	inch	1.25 – 2.5	1 // 0*
Hygiene	hand /palm	10 -12.5	1 // 0*
Dishes	elbow	25 – 30	1 // 0*
Clothes	arm	50 – 60	10 // 2000**
Cleaning	breast	90 -120	10 // 2000**
WC	full length	180 -210	10 // 2000**

Table 2: Numerical transformation of water use and probable equivalence in classical water quality parameters for (*) drinking water (JO 2007) and (**) swimming water (JOCE 1975). The latter does not give turbidity but only transparency in Secchi.
1 m Secchi was converted to 10 NTU.

To compare statistically the choices of French and Brazilian user population, the data of household uses, proposed for rainwater and obtained from questionnaires, were transformed to numeric values according table 2, before treatment.

Assuming (Yan et al. 2005) that the "choice of the participants" is normally distributed and related to distance of its log, the data could be fitted through non linear regression using classical S-curved response model from population biology (Litchfield & Wilcoxon, 1948). "The effective distance designed by 50% of the participating population" and its 95% confidence limits, was used as final parameter for comparison. The calculation was done with Prism software (GraphPad, 2009).

3 RESULTS AND DISCUSSION

Due to different functions of the buildings the users' profiles are slightly different (Table 1 and 2). The ENPC building is 8 times bigger than Rokaz with more diversified uses, being mainly office space, partially laboratories with only small leisure equipment. The typical ENPC user is for this reason older (33 years), with higher education and spends almost 8 hours in the building during the day. The typical Rokaz user is younger (26 years), with less education and spends about 2 hours in the building

principally in the afternoon and in the evening.

Parameter	ENPC, Paris France,	Rokaz, Belo Horizonte Brazil,
Screened population	1200 (*) (800 students + 250 research + 150 staff memebers)	160 (150 pupils + 10 staff)
Nr responded (%)	285 (mean of 24%, with 19% graduate students, 23% R&D, 48% administrative corps)	62 (39%)
Male/ Female distribution	57.1% – 42.9%	56.9% -43.1%
Age distribution	mean=32.9; std=12.7	mean=25.7; std=5.2
Education level	80 % graduate or more	67% graduate or more

Table 3: User populations compared

3.1 Water perception

The perception of rain water harvesting is most probably linked to rainwater, the water availability and more generally to the access to drinking water. For this reason one of the first questions concerned by the perception is the quality of tap water.

In France there is only slight doubt about the quality of tap water (figure 2). Only 5% indicate lack of potability and 8 % have doubts. Almost 90% of the users are convinced of the adequate quality of tap water. There are no significant differences between men and women or between students and administrative employees. On one hand the metropolitan region of Paris and France in general, has excellent indicators for water supply and on other hand France has a culture of drinking water. In France it's a widespread custom to serve tap water with all meals and in restaurants it has to be for free (DGCCRF 2009). So the results above reflects the balance between the trust in water distributing companies, custom of drinking water at the table and the publicity of the bottled water industry.

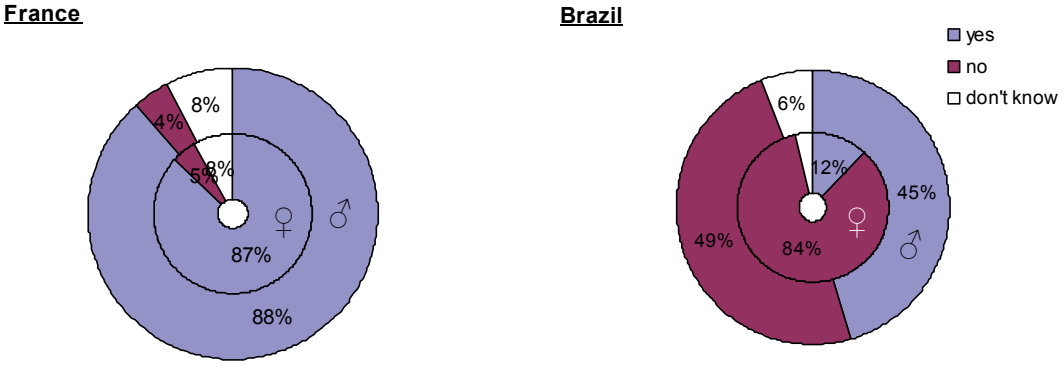


Figure 2. Perception of potability of tap water in France and in Brazil, including the difference between both sexes, women: inside part and the men: outside part. The chart gives the percentage of total responses on the question "Do you think the tap water is suitable for drinking".

Brazil gives a quite different image than France. Even though the city of Belo Horizonte has one of the best water supply indicators of the country and the region of the Climbing School Rokaz has the same HDI (0.961) as France (PNUD 2009), there is a lack of confidence in the quality of tap water especially by the women. More than 50% of the female visitors has doubts and think that the tap water is not suitable for drinking (Figure 2). We remarked a difference if we asked about "potability of water in the bathroom" and "suitability of tap water for drinking". Especially for women the doubt increases (from 56% to 84%) when we talk about "drinking".

Another factor which may contribute to the lack of appreciation of tap water might be the absence of "free" drinking water at table, water being replaced by more 'in vogue' drinks such as vodka, soda or fruit juice.

Doria et al. (2009) found comparable differences between UK and Portugal, indicating that the perception of risks associated with tap water is moderately at table, water by explained by flavour, memorability, context, negative information from friends and seems to be directly influenced by trust in water companies. They observed that in Portugal the bottled water consumption was three times as high and the tap water consumption for drinking, two times lower than in UK, despite similar

appreciation of the water supply services.

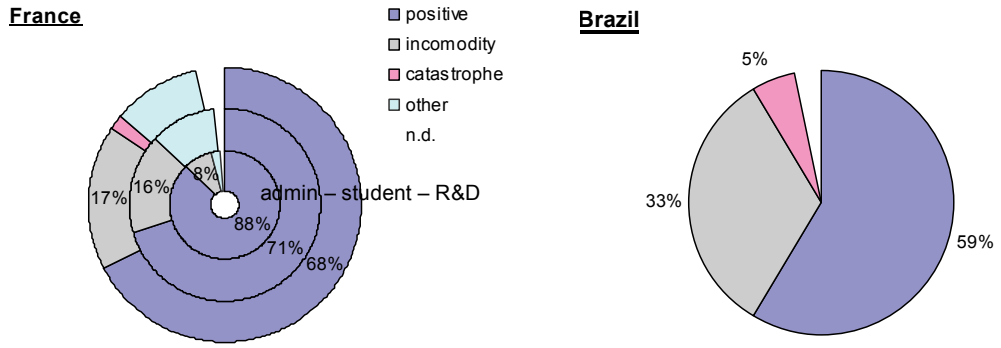


Figure 3. Perception of rain in France and in Brazil, including the difference between the users types in the ENPC building.

The perception of “rain” (figure 3) is another interesting example of difference between the Parisian region and Belo Horizonte. In both cases rain is seen as something positive, more as a gift from the nature than a natural catastrophe. No significant difference (>5%) was found between male and female users in France nor in Brazil. However we found significant difference (9-20%) between the different users groups of ENPC. Among the ENPC users, the administrative personnel is the most optimistic, mentioning the inconvenience only in 8% of case and not even mentioning natural catastrophes. Researchers are the least position about rainwater, even linking it to catastrophe in 1 case. Another difference between these groups at the ENPC was the free response category, 10% of R&D and graduate students preferred to give their own vision than the proposed ones. In general the users give positive vision or mentioning topics linked to their research like “live”, “earth shower” or “my PhD”.

In Brazil there is a clear distinction between positive and negative perception. The majority (59%) see rain as “resource” which can be explained probably on one hand by the long period (4 -5 month) of dry weather with absence of rain, and on other hand by the wide promotion of rainwater harvesting programs in the rural area of Minas Gerais. The incommodity in Belo Horizonte is quite different from the “cold of rain” perceived in Parisian region. In Belo Horizonte the rain is always refreshing due to a mean temperature of 30°C in the rain period, but the tropical character of the rains, such as high intensities, perturbs strongly the public services of Belo Horizonte. An important rain event causes principally local flooding, impeding the public transport and generating shortcuts in the electricity network even in high-income regions.

3.2 Water use

Each water use needs a specific water quality. For example in France, drinking water should be free of pathogens and contain zero E.coli (JO 2007) and swimming water should contain less than 2000 E coli per 100 mL(JOCE 1976). The user ”knows" the water he needs and can estimate roughly its quality and the risk he takes using a given type of water. Rainwater harvesting and use of rainwater will only be successful if the user estimates there will be no disadvantage or risk using rainwater instead of tap water. For this reason we have asked about actual uses (tap water) and possible uses of rainwater.

The user was asked to mention possible uses of the rainwater collected. The question was general and not linked to the eventual use of rainwater in the building in the future. The figure below resumes actual uses and the proposed uses in the ENPC building. The only use or “demand” which can be fully satisfied by rainwater is the use for toilet flushing (figure 3). No straight relation could be found made between all current uses (drinking water) and use proposed for rain water. For the high water quality uses (1 to 4 in figure 3) no relation was found between tap water uses and rain water uses proposed. However for the low quality uses (5 to 8 in figure 3) the proposition for rain water were for more than 90% the same as the current uses of tap water. If a user marked cleaning as a current water use in the ENPC building he marked also cleaning as a possible use for the harvested rainwater.

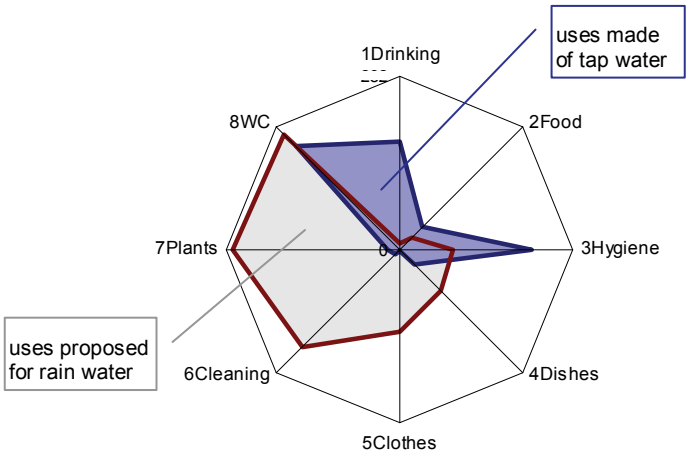


Figure 4. Drinking water uses at ENPC building and proposition for rain water uses.
Full scale represents 100% of the screened cohort. The perceived water quality is decreasing from 1 to 8.

If we look closer at the proposition for rainwater use (figure 5), we can see that the number of user proposing a high quality use, like drinking water, for rainwater is much lower than for low water quality use like flushing of the toilets. This relation can be found for the ENPC building as well for the Rokaz building. Though the precision of questionnaire in France was higher (more detailed separation of answers); the global trend is the same. In France almost nobody is proposing rain water for drinking but in Brazil 25% of male users has proposed it. The same kind of difference can be found for personal hygiene, where the difference is even higher.

The male / female difference in Brazil is somewhat surprising, considering that the activity is high economic class activity and that the average education level is quite high. 84% of female users have at least graduate study against 55% for the men. The high acceptance for rainwater as drinking water or water for personal hygiene might be explained by the fact that the indoor mountain climbers spent a lot of time outside in the nature where water from natural resources can be used without any problem.

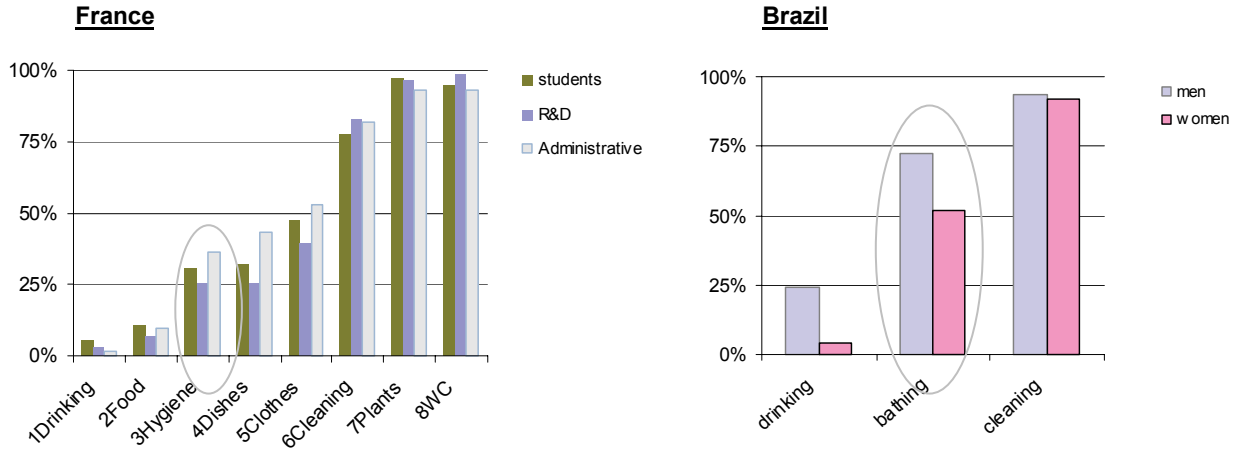
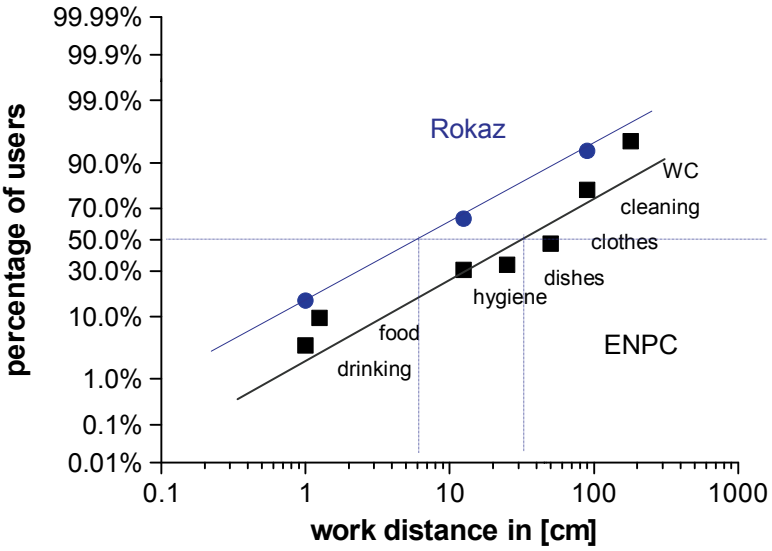


Figure 5: Rainwater uses envisaged by ENPC and Rokaz users. The percentage indicates the part of the responses and having attributed rainwater to a particular use.

In France no significant difference (<5%) was found between male and female users, though significant difference was found between R&D and administrative personnel (cf. figure 5). We found the biggest differences (in average 13%) in the proposition for personal hygiene, washing dishes and clothes. The administrative personnel propose more frequently these uses than the R&D personnel. In practice we would suppose the contrary, assuming that R&D is better aware of the real (low) health risk of rainwater use for these purposes. Similar stake holder difference was also found by Baggett et al (2006) and Poyhonen (2000) for waste water reuse.



Best-fit	Rokaz	ENPC
EC50	6.711	35.84
95% Conf. limits	4.817 - 9.349	22.78 - 56.39
R^2	0.9973	0.9358

Figure 6: Estimation of perceived rainwater quality for ENPC and Rokaz users

Figure 6 shows the raw water quality data attributed to rainwater (figure 5), after transformation to “acceptable working distance”. Though these distances are approximate and need to be confirmed, we can determine after normalization a good correlation (r^2 = 0.99) between the distance or risk and the number of users having designed it.

We find a mean acceptable working distance of 6.7 cm (4.8 – 9.3) for Rokaz and of 35 (23 - 56) for the ENPC users. This means that the median of Rokaz users has attributed to rain water to be harvested, a water quality acceptable for personal hygiene. The median attributed by the ENPC users is higher, attributing a water quality, lower than needed for cleaning clothes.

The results above corroborate the findings of Marks et al (2008) and Hurlimann et al (2006), if rainwater harvested is defined as recycled water, suggesting that there is a hierarchy, or "ladder of acceptance" in relation to the different uses (qualities) of recycled water so that opposition decreases as likelihood of human contact decreases.

The difference between ENPC and Rokaz can be probably explained by the different social economic context between the Parisian region and the city of Belo Horizonte. The Brazilian users accept a higher level of risk and attribute higher water quality to the rainwater. This higher risk level acceptance may originate in the outdoor character of the activity of Rokaz users, but also in the higher social risk levels in the Brazilian society like health (for example higher under five mortality) and security (for example higher level of homicide).

Though the perception and the acceptance for rain water uses was different, the vision of rainwater harvesting was the same in the ENPC building as in the Rokaz building, more than 90% of user has a positive vision of rainwater harvesting. The proposition to use harvested rainwater for flushing of the toilets was even approved by 95% of all users.

4 CONCLUSION AND PERSPECTIVES

The results indicate difference of perception depending on socio-economic context, on sex and on professional occupation. The Brazilian users mistrust much more the quality of tap water and have more pessimistic perception of the “rain” than French people. The male Brazilian user accepts more risk, accepting in 25% of cases, rain water even for domestic use such as drinking water. In the French situation we have identified in 10% of cases more positive perception of administrative personnel than of the R&D personnel and no difference between male and female users.

From statistical treatment we can conclude that the water quality attributed by the users of both buildings to rainwater harvested is different. The Brazilians attribute a better water quality to the rainwater than the French, probably due to higher risk level acceptance.

Though both populations show a good acceptance of RWH and (re)use of water harvested, at least for uses like cleaning and toilets, the field implementation will depend most probably on balance the decision makers make between established politics and the level of investment.

Ongoing research should bring more insights in the quantitative and statistic aspects of the perception mapping, validating the relations proposed. Bad operation and maintenance is cause of the break-down of many technologies set up, and should therefore get sufficient attention in the research through reflection on adequate technical, social and management indicators.

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