Non-potable water systems: a sustainable solution or a risk to users?

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Abstract

Water shortage has improved management processes, waste control, and procedures and use of alternative sources of water not only in public systems, but also in building systems. Several initiatives exist to use non-potable water systems in residential and office buildings. Unfortunately, however, these initiatives have little technical support, nor any regulatory norms or legislations to guide managers and professionals on appropriate management and monitoring practices. This situation may put the safety of users and the success of the technology at risk. Considering that to produce a quality building, it is essential to take into account the needs of users, a performance evaluation of non-potable water systems becomes an important tool for the improvement of these systems and for the reduction of health-related risks to users. This paper, thus, aims to evaluate the performance of non-potable water systems of three residential buildings, with regard to design, implementation, operation, and maintenance. For the performance evaluation, case studies were carried out in residential buildings with non-drinking water systems. The results in the cases under study show a lack of systematic water quality control, the occurrence of cross-connection, the absence of identification of the specific type of water conveyor, and of booklets or guides for users. Therefore, these results highlight a lack of technical training of designers, builders, managers, and users and the absence of a specific legislation or of technical standards to regulate such systems. In conclusion, the cases studied are characterized by systems that operate with less-than-adequate performance to meet the needs and ensure the safety of their users.

Keywords
Non-potable water system, water reuse, performance evaluation.

1 Introduction

The use of non-potable water is a reality as an alternative source of water supply for buildings. For this reason, the technology for water treatment systems in buildings has been developed, yet much mustbe done to ensure the safe use of non-drinking water in buildings.
Security during implementation, use, operation, and maintenance of non-potable water systems in buildings depends on the management of consumption, water quality, and of the risks involved in all stages of the process, but not alwaysare these requirements observed simultaneously.
One of the impacts of non-potable water use in buildings that most encourages users is the reduction in the consumption of drinking water. A study conducted in five single houses with treatment system and reuse of greywater in England for a year points out that the use of non-potable water in water closets resulted in a 9-to-36% reduction in the consumption of drinking water in these units[1]. Another study conducted in Malaysia offers even greater values, witha reduction of up to 40% of potable water consumption in residential buildings equipped with this type of system[2].
The results are not always favorable to the reduction of drinking water consumption and, in many cases, no water consumption management takes place. This can be shown in a research study conducted in an office building in Brisbane, Australia, with a non-potable water system using rainwater. The results show that the system was only moderately reliable to meet the demand owing to operational problems. The analysis of the study shows the need to include validation and monitoring to ensure that the system is operating according to the purpose of theproject[3].
Another aspect for the success of this technology is the perception of users. In this regard, a research study conducted in the municipality of SantCugat, Spain, where the implementation of non-drinking water systems is compulsory in new buildings, the results show that the users' perception is very vulnerable to any failure that may occur in the system. Health hazards, operation, costs, and environmental awareness are, to varying degrees, essential for public acceptance[4].
With respect to health risks, a case of a project funded by the Dutch Governmentillustrates the problem. In a housing estate, although a number of precautions were taken during the design phase, some running errors contributed to contaminate drinking water in 1,000 dwellings due to a cross-connection between the potable and the non-potable water supplysystems[5].
This article, therefore, aims to evaluate the performance of three residential buildings, with one or more housing units, with non-potable water systems and to show the different faults that occurred due to lack of training of professionals of the design, implementation, operation, and maintenance of such developments.

2 Potable and non-potable water systems in building

A building water system features two subsystems of water: potable and non-potable water, as illustrated in Figure 1. Thus,different types of non-potable water sources for residential buildings include rainwater, wastewater and underground water, after treatment.

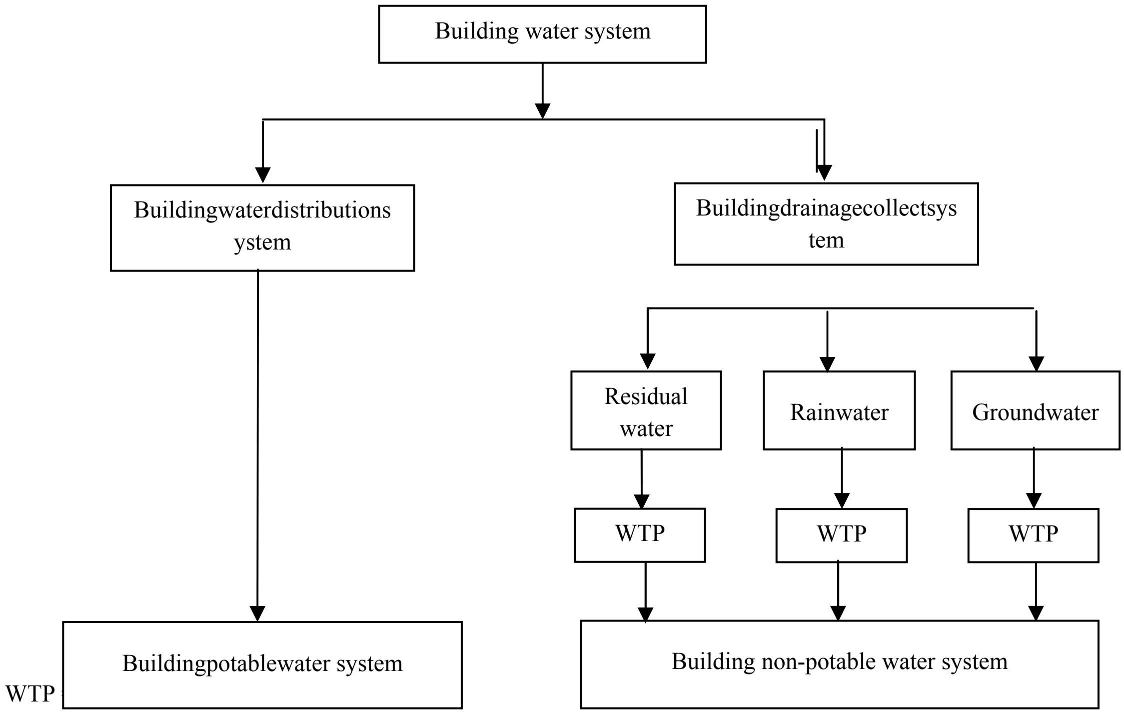

Figure 1 Building potable and non-potable water systems[6]

These features of the non-potable water system make it more vulnerable to risks of contamination than a conventional system of potable water, where only drinking water circulates in reservoirs and at all points of use. Figure 2 shows the types of non-potable water systems according to the generating water source and possible applications in residential buildings.

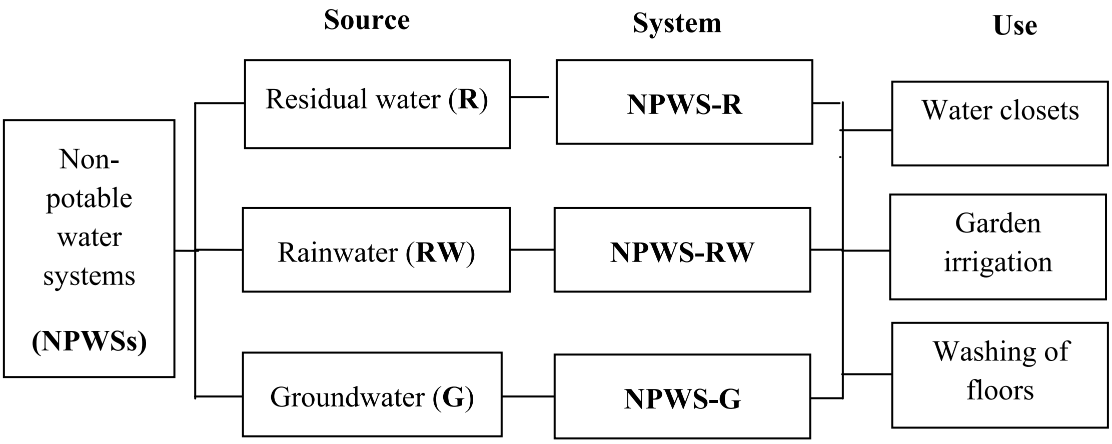

Figure 2 Non-potable water systems with different sources and uses in residential buildings[6]

From the different sources of non-potable water, the presentauthors[6]offer the classification of the following types of non-potable water systems for residential buildings:

- Non-potable water system-recovered (NPWS-R)

Set of pipes, tanks, equipment, and other components intended to collect greywater or blackwater, store, treat, and distribute the treated greywater or blackwater, the goal of which is to reduce both the demand for drinking water and the sewage volume for the collection, transportation, and treatment of toilet sewage.

- Non-potable water system-rainwater (NPWS-RW)

Set of pipes, tanks, equipment, and other components intended to collect rainwater, store, treat and distribute the treated rainwater, the goal of which is to reduce both the demand for drinking water from public or private networksanddampen the flowrates in urban drainage system.

- Non-potable water system-groundwater (NPWS-G)

Set of pipes, tanks, equipment, and other components intended to collect groundwater, store, treat, and distribute the treated groundwater, the goal of which is to reduce the demand for drinking water from public or private networks.

3 Methodology

The method adopted is that of case studies because it aims to understand and describe the way by which the non-potable water systemis usedin residential buildings, where several factors, such as training of professionals in operational and maintenance procedures, influence the performance requirement of "security in the use of water".

The studywas developed in the following stages:

- characterization of the condominium;
- characterization of the non-potable water system;
- semi-structured, face-to-face interviews with users and operators of the system, analysis of documents, in cases when this material was available, and unsystematic direct observations during field visits;
- from the data collected, a general narrative was drawn up foreach visited building by registering each case as a complete study.

4 Results and discussion

The characterization of the three condominiums under study, the description of the non-potable water systems, and the problems encountered are set out and discussed below.

4.1 Case study A

This is a condominium with seven 28-storey buildings, 392 apartments, and 1,500 inhabitants.
The sources of supply of the NPWS are: greywater collected from showers, washbasins, and washing machines; groundwater from drainage wells; and rainwater collected from the roofs and condominium floors.

The rainwater does not receive the same treatment as the greywater and groundwater. Rainwater is filtered and conducted tothe non-potable water reservoir. The greywater and groundwater are treated through the addition of chemical products by automatic feeders. The quantities and periods of addition of chemicals are programmed by system operators.

The identification of containers of chemicals that fuel the system, however, does not correspond to those found in the feeders. Thus, it cannot be confirmed if the chemicals used remain those defined during the project phase. After chemical treatment, the water passes through a filter.
The non-potable water obtained after treatment is conducted to the underground tank of non-potable water, where a blue dye is added. Thenon-potable water is conveyed to the upper reservoirs of each one of the condominium towers.
A foul smellwas observed in the underground non-potable reservoir. There is an entering point of drinking water supply in the underground tank that can be used to supply the NPWS in case of system failure.
Regardingpipe identification, there is not a different color for the NPWS. Green stretches of non-potable water pipes were observed, the same color as that used for drinking water pipes, as illustrated in Figure 3. Pipes of different colors were used, without identification of the type of water theyconvey, with a risk of cross-connection in future maintenance or system changes.

Figure 3 Pressure reducing station of non-potable water with the same color as that of the drinking water pipes

A cross-connection was detectedright afterthe system was put into operation. Some users installed a hygienic shower in bathrooms by adding an extension to the water branch of the water closet without knowing that that stretch of pipe was being fed by non-potable water. During the testing phase of the NPWS, the addition of a dye to non-potable water identified this irregularity in the installation of hygienic showers.
Inadequate quality of water was detected in one of the drainage wells used as a source of groundwater, which went on to havea foul smell. The laboratory analysis of water samples from this well had characteristics that were not in compliancewith the use for which it was intended and, therefore, it is no longer used as a source of NPWS.

The users received information about to the NPWS through letters, communications on elevator bulletin boards, and emails. This information is offered to new residents when they register for access to the condominium. No guides or manuals exist to inform NPWSoperators orusers about the risks inherent to the system, and no newsletter about its operation and maintenance is made available.

The condominium doesnotmanage water and energy consumption levels, which does not afford an analysis of whether or not a reduction impactof these inputs has occurred.

4.2 Case study B

This is a condominium with four 22-storey buildings, 264 flats, and 898 inhabitants.
The original design did not provide a non-potable water system for the building. The users decided to implement a system to make use of rainwater in order to reduce drinking water consumption. In addition to the rainwater collected from roofs and floors,water from washing the filters of the pool is also used as a source of NPWS supply, owing to an understanding that the chlorine present in this water helps disinfect the storedeffluent.
Non-potable water does not receive any kind of treatment, and it is only used to wash the floors of communal areas. There is no pipe conveying non-potable water from the reservoir to the points of use. A pump and a hose were installed in this reservoir. The floors are washed with this hose, using non-potable water pressurized directlyfrom a pump. When the reservoir cover (Figure 4) was open for inspection, plastic packaging waste was found in the water, as can be seen in Figure 5.
Pipes remain brown for rainwater pipes and not purple as an indication of non-potable water. No points of use are fed by non-potable water. The water is used by means of a hose installed in the reservoir. Neither is there any type of signage or identification at the point of non-potable water. The water does not receive the addition of a dye to differentiate it from drinking water,nor does it undergo monitoring or quality control.

Figure 4 Access cover of the non-potable water reservoir

Figure5 Inside the non-potable water reservoir

System management is performed by the janitor, who does not maintain a preventive maintenance routine.
No guides or manuals with technical guidance of the system are available to the NPWS operators or to the users. Those responsible for the operation of the system received only verbal guidelines. The usershave never been informed about the risks inherent to a non-potable water system, nor have they received any information on the operation and maintenance of the system.
The condominium does notmanage water and energy consumption levels, which does not afford an analysis as towhether or not a reduction impact of these inputs has occurred.

4.3 Case study C

This is a horizontal condominium with eight dwellings, designed under the ideal of a sustainable construction, located in a densely-wooded terrain and with a population of 31 people. The eight houses are high off the ground, and they have terraces and private gardens that integrate with collective-use areas.
As sources of supply, the non-potable water system uses wastewater, consisting of greywater, and blackwater, collected from all the sewage from the houses, and groundwater taken from a well. Only the wastewater passes through a treatment system. After treatment, the non-potable water is used for flushing inwater closets, floor cleaning of common areas, and irrigation of gardens and the collective vegetable garden. Rainwater is not used.
The treatment system used is the physicochemical and biological type and the addition of chlorine to non-potable water is made manually by a condominium employee weekly. The water collected from the well doesnot pass through any treatment and is conducted directly to the undergrounded tank of non-potable water. The water in the undergrounded tank and in the well has a cloudy appearance, as can be seen in Figure 6.

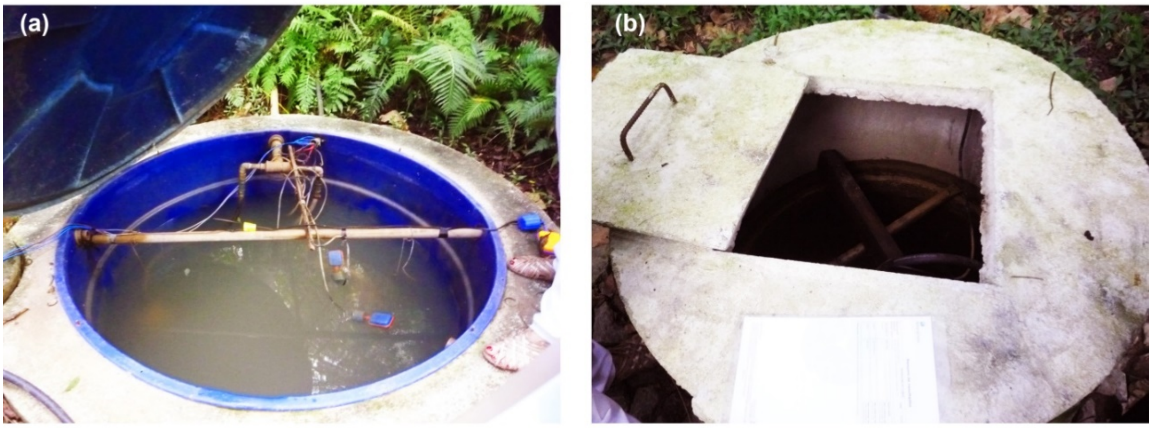

Figure 6 Aspect of the water in theundergrounded tank (a) and in the well(b)

From the undergroundedtank, non-potable water is conveyed to the roof tank. This reservoir can be filled manually by drinking water, in case of failure in the NPWS-R. Non-potable water is distributed by gravity to the points of use.
The NPWS-R piping does not show differentiation by color or identification of any sort. In addition, the same type of pipe was usedfor the distribution of both drinking water and non-potable water. Figure 7 shows the pipes inside the shaft of one of the houses.

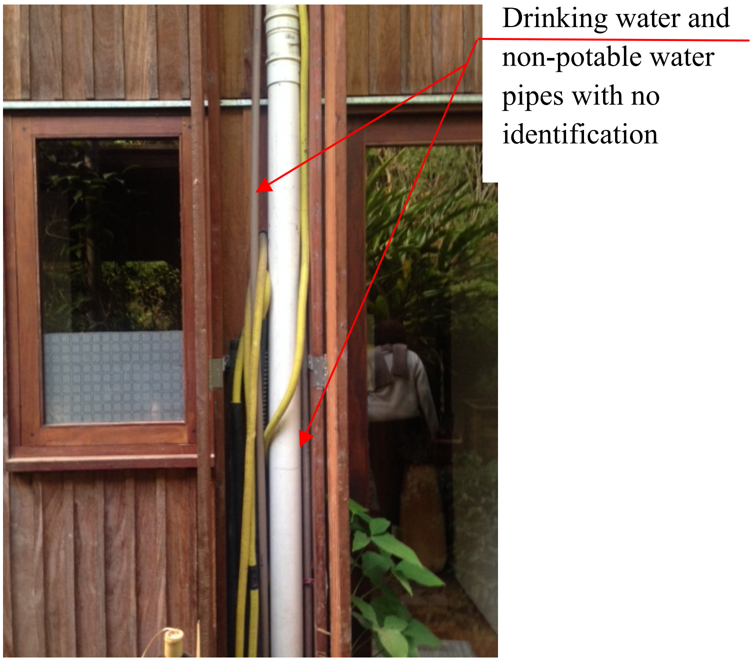

Figure 7 Inside a shaft with no identification that differentiates the pipe systems

The NPWS-R management is performed by the condominium janitor.Only corrective but no preventive maintenance is performed in the system. Follow-ups with visual inspection and cleaning without disinfection of reservoirs occur monthly.

In 2014, a cross-connectionwas reported in one of the houses. After an installation of a hygienic shower,next to the water-closet,the users noted that the newly-installed sanitary equipment ran out of water during the period in which the NPWS-R was turned off for maintenance, which indicated that the hygienic shower was being fed by non-potable water.

The condominium does not routinely control non-drinking water quality, but in early 2015, the residents noted that the non-potable water was of an unpleasant color and odor, causing stains on water closets. For this reason, water samples from the non-potable-water roof tank and from the well were collected and sent for laboratory analysis.

The sample from the non-potable-waterroof tank showed non-compliance for the following parameters: total dissolved solids andthermotolerant coliform bacilli. The well water sample showed non-compliance for: color, pH, turbidity, total coliform bacilli, Escherichia coli, and heterotrophic bacteria count.

Despite the non-compliance instances identified in laboratory reports, the NPWS-R was not disabled. For security reasons, the condominium decided no longer to use non-potable water in the irrigation of the collective vegetable garden.

No booklets or manuals exist with technical guidance on the operation and maintenance of the system. Employees were advised verbally on how to operate and maintain the system. The residents received the information during a meeting with the engineer responsible for the project, having been made aware of the risks inherent to the system. There is no periodic recycling of this technical information and users are informed by emails about the maintenance of the system and of all the condominium, as interventions occur.

The condominium doesnot manage water and energy consumption levels, which does not afford an analysis as to whether or not a reduction impact of these inputs has occurred.

4.4 Results and discussion

Categories were established from the information obtained in the case studies, which enabled a general analysis of the evidence obtained. The six categories set out are: water supply, treatment system, installations, points of use, and operation of the system.

- **Watersupply**

This category shows that two condominiums aresupplied with rainwater and groundwater, one with greywater and blackwater, and the other with rainwater and the effluent of a pool.
Among the dwellings that use rainwater, none offers an automatic system for disposal of the first water that runs down the roofs and other collectingsurfaces. Rainwater comes from the roofs and floors, without any separation.

- **Treatment system**

In analyzing this category, it was verified that one of the buildings does not have a collected effluent treatment system. Regarding the two condominiums that have treatment stations, in one of them, based onlaboratory analysis water qualitydata, it was found that the treatment process is not suited to the source used, and produces water of a lower quality than is required for its intended activities. For the other two, insufficient data prevent such an evaluation.

- **Installation**

In this category,it is possible to say that none of the case studies offered differentiation of non-potable water pipes by color.
In one of the case studies, the non-potable water tank does not have any components that allow supplyingit with drinking water, in case of operational failures in the NPWS. Of the two projects that count on a drinking water supply point in the non-potable water reservoir, one does not have a reflux prevention component of non-potable water at the drinking water supply pointand in the other, it was not possible to confirm the presence of the security component.

- **Points of use**

In this category, two of the condominium buildings use non-potable water for water closetflushing, two of them, for cleaning floors, and one of them, for irrigation of gardens.

Only one of the developments has differentiation of NPWSpoints of use by color, only one of the three condominiums had signs at points of use, alerting users as to the distinct quality of water, and none of them keeps restricted access to non-potable water.

- **Operation**

In this category, only one of the condominiums performs a continuousaddition of a dye to non-potable water to differentiate it from drinking water. Only one of them carries out preventive maintenance of the system.The other two onlyconduct corrective maintenance. Most of the time, the system management is carried out by the janitor or another

employee of thecondominium. Only one of the buildings has hired a company specialized in management.
One of the condominiums undergoes water quality control, with periodic laboratory analyses of water samples collected in the system. None of the buildings visited manages non-potable water or electric power consumption of the system. Thus, they cannot assess the performance of the NPWS with regard to water and energy consumption.
Concerning occurrences and irregularities identified in the NPWS during operation, two condominiums reported incidents of cross-connection in the system and verified that low-quality non-potable waterwas produced for its intended use.

5 Final considerations

The NPWShave been implemented in residential buildings in Brazil as an alternative source of water in order to reduce potable water demand. The evaluation carried out in three condominiums shows that the scenario is characterized by NPWSsthat operate with less-than-adequate performance to meet the needs and ensure the safety of users. Among the critical points are the following:

- the supply source changed without changing the treatment process;
- the absence of quality control of non-potable water prevents the assessment of the treatment system, for in monitoring the characteristics of the water produced, the efficiency of the treatment plant is also monitored;
- the systems do not follow the standardization of color, nor do they have water quality information, which increase the risk of cross-connection;
- managers, operators, and users have no manual or booklet available with information on the risks inherent in the system and recommendations for its operation and maintenance;
- two of the three cases studied showed inadequate quality of the water produced and two, cross-connection, situations that expose users to health hazards.

Finally, the results of the case studies show that the success of this type of system depends on the existence of procedures, technical manuals, and regulations that guide practitioners, managers, and users about the implementation, management, and monitoring of these systems to ensure the quality of the water produced and prevent any risks to users and to the environment where they are found.

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7 Presentation of Authors

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