Reuse of grey water in buildings. Technical, environmental and health aspects

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Abstract
Growing interest in the reuse and recycling of grey water in buildings is being shown in many countries, for reasons of sustainability and rational water use. In Portugal, the National Association for Quality in Building Services (ANQIP), a NGO that promotes quality and efficiency in the water cycle in buildings, has recently decided to develop a technical specification in this field. This paper presents a detailed analysis of this new specification, looking at some technical aspects of the installations, with special attention to the quality requirements of the treated water, according to the possible uses allowed.
1 Introduction

Water has become a resource of the utmost importance. Demographic growth and, most especially, economic development and today’s lifestyles have rendered drinking water scarce, and its status has changed over the past decades from that of a community and national asset to that of an economic one.

Climate change has worsened the situation and it is predicted that in certain countries, such as Portugal, the forecast reduction in rainfall or the alteration of its regime could have a negative effect on situations of crisis in the short to medium term.

So, for reasons of sustainability and rational water use, a growing interest in the reuse and recycling of grey water in buildings is being shown in many countries. In Portugal, the National Association for Quality in Building Services (ANQIP), a NGO that promotes quality and efficiency in the water cycle in buildings, has recently decided to develop a technical specification in this field [1].

This paper presents a detailed analysis of this new specification (ETA 0905), looking at some technical aspects of the installations, with special attention to the quality requirements of the treated water, according to the possible uses allowed. On the single-family scale, however, the specification allows treatment systems simpler than those given in this ETA, as long as they respect the applicable legislation and remain the responsibility to the owner.

A Safety Plan must be prepared with an initial version the installer’s responsibility, but periodically updated by the user. The Safety Plan must include, at least, a description of the installation, a risk analysis, the criteria for the evaluation of the conformity of the quality of the water and the procedures in the event of a fault or serious problem (Action Plan).

Maintenance requirements are also examined, along with the creation of a certification procedure for systems so as to guarantee the overall quality of installation from the technical point of view, and the protection of public health.

Finally, the standards used in several countries are compared and some aspects of those where there is a broad agreement are analyzed. Aspects of those systems where there is currently a certain amount of doubt are also examined, and the differences between the standards used in several countries are indicated.

2 The principle of the 5R for the water efficiency in buildings

Efficient water use in the urban cycle can be summarized as a principle analogous to but more comprehensive than the 3R principle (used for waste) which is known as the 5R principle (Figure 1) [2].

- **Reduce Consumption**
- **Reduce Losses and Waste**
- **Reuse Water**
- **Recycle Water**
- **Resort to Alternative Sources**

_**Figure 1 – The 5R principle for water efficiency in buildings [2]**_
The first R - Reduce consumption, passes through the adoption of efficient products or devices, notwithstanding other non-technical measures (economic and sociological).

The second R - Reduce losses and waste can involve various interventions, e.g., control of losses in toilets or the installation of circuits of circulation of hot water.

The reuse and recycling of wastewater (or grey water), whose difference is to consider using a "series" or the reintroduction of water at the start of the circuit (after treatment), are included in the third and fourth R, and, as mentioned above, ANQIP developed a specific technique for this (Technical Specification ETA 0905).

Finally, the use of alternative sources may involve the use of rainwater, ground water or even salt water.

It should be noted that the ANQIP has already devised a certification and labeling model for water efficiency for products and a technical specification for the use of rainwater in buildings [3][4]. The Specification ETA 0905 defines as grey water the domestic waste water with a lower concentration of pollutants that can be considered for recycling or reuse. In residential buildings this water generally comes from the discharges of baths, sinks and showers but, in certain conditions, the discharges from washing machines or even wastewater from kitchens can also be considered.

The grey water treated for reuse purposes, satisfying the quality criteria established for the uses for which it is intended, is called "regenerated water".

3 Health concerns

The water security has been consolidating itself as a global concern to ensure the health of populations.

In this sense, was published by the International Water Association the Bonn Charter for the supply, which describes the institutional and operational conditions to manage the water supply from the source to the consumer, in accordance with WHO guidelines. In this perspective, the management and control systems should be based on a Security Plan, taking into account the resources, the available technology and the reality in each country.

The Portuguese Specification ETA 0905 states that a Safety Plan must be also prepared for the systems of reuse and recycling of grey water in buildings (SPRAC), with an initial version the installer’s responsibility, but periodically updated by the user.

This Safety Plan must include, at least, the following chapters:

- Description of the installation;
- Risk analysis;
- Criteria for the evaluation of the conformity of the quality of reclaimed water (minimum frequency of analysis for the various installation operation periods, etc.);
- Procedures in the event of a fault or serious problem (Action Plan).

In general, it can be noted that the Portuguese Specification is more exacting than the recommendations of the German Association for Rainwater Harvesting and Water Utilization (FBR), but less demanding than the Spanish Royal Decree 1620/2007. Most of the recommendations of the FBR (Information Sheet H201, 2005) were also included in the ETA 0905, but the latter is more demanding in some aspects, such as the need for a Security Plan and the requirement for analytical checks at various stages.

The Spanish Royal Decree, on the other hand, appears too demanding in terms of the parameters for analyze and requires an excessive frequency of checks, which has discouraged the implementation of such systems in Spain. However, it is known that the Decree will be revised soon to ease the control and their costs.
For technical and public health reasons, the SPRAC must be certified under the terms of the Technical Specification ANQIP ETA 0906 [5], which requires the prior examination of the project by ANQIP, inspections to the construction, certification of installers, as well as the Safety Plan also approved by ANQIP.

Since it is a specification of a nongovernmental entity, the ETA 0906 specification is, till the moment, of voluntary compliance. This is undoubtedly a less positively aspect in the Portuguese approach, since, being able to involved public health issues, the certification of the installations should have a mandatory character.

However, the European Commission is developing studies and proposals in this regard, so it is predictable that in the short/medium term, the mandatory certification of these systems may be the norm within Europe.

4 Quantity and quality of grey water

The quantity of grey water produced can vary considerably depending on the sanitary habits and living standards of families.

In the absence of specific studies, in new or rehabilitated buildings, and assuming that the devices installed are at least Class A (in the Portuguese system of labeling and certification of water efficiency of products), the average water consumption can be estimated at about 100 l/(inhab.*day) and gray water production is about 70 l/(inhab.*day) (Table 1). These values are similar to those proposed in Germany by FBR [1].

According to this estimate, the potential for reuse is around 48 l/(inhab.*day), of which 25 to 35 l/(inhab.*day) can be used in toilet cleaning.

Information on the water balance in residential buildings presented in Table 1 can be adapted to non-residential buildings, through a case study.

<table>
<thead>
<tr>
<th>Nature of the water used</th>
<th>Use of water</th>
<th>Wastewater produced</th>
<th>Destination of water</th>
</tr>
</thead>
<tbody>
<tr>
<td>52 litres of water of drinking quality</td>
<td>40 litres for showers, baths and basins</td>
<td>70 litres of grey water</td>
<td>48 litres of regenerated grey water</td>
</tr>
<tr>
<td></td>
<td>12 litres for the kitchen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>48 litres of regenerated water</td>
<td>5 litres for cleaning</td>
<td>25 litres of black water</td>
<td>22 litres of discharged grey water</td>
</tr>
<tr>
<td></td>
<td>13 litres for the washing machine</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>25 litres for flushing toilets</td>
<td></td>
<td>25 litres of discharged black water</td>
</tr>
<tr>
<td></td>
<td>5 litres for watering</td>
<td></td>
<td>Infiltration in the soil</td>
</tr>
</tbody>
</table>

The production of grey water and its pollution levels are essentially determined by the habits of consumers.
The substances present in grey water usually result from personal hygiene products, detergents, hair, skin, particles of dandruff and possibly dirt from clothing, and is easily biodegradable. Due to this biodegradability, treatment cannot be too retarded as decomposition processes involving sulphates and unpleasant odors can be unleashed.

In general, the water from showers and baths is not very polluted. Water from washing machines usually has a higher pollutant level and water from the kitchen (sink and dishwasher) even greater. Values may vary depending on the quality of the tap water or treatments carried out in the building network (for example, a higher concentration of nitrates in the overall network or the addition of polyphosphates in the building installation to prevent the corrosion of the pipes). Relatively high concentrations of phosphates may result from dishwashing detergents.

A large number of microbiological studies performed in recent years in bath, shower and sink waters showed much lower levels of total and faecal coliforms (E. coli) in comparison with total domestic wastewater. It is worth note that in the effluent from washing machines, the concentrations of bacteria depend on the washing temperature.

In terms of present knowledge, it is considered that regenerated water can be used in flushing of toilets, washing clothes and watering gardens, after appropriate treatment. The systems shall be provided with sampling points before and after the treatment. The quality is considered adequate if, in yearly analytical checks, no parameter exceed the specific Maximum Admissible Value (MAV), with the tolerance given in Table 2 and, in the latter case, a confirmatory analysis carried out after inspecting the installation, and within a maximum of 15 days, leads to a new value that complies with the MAV. During the start-up phases the grey water cannot be reused in the building. The user of the regenerated water is responsible for preventing the deterioration of its quality between the treatment and use locations.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tolerances pertaining to MAV</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Legionella</em> spp.</td>
<td>1 logarithmic unit</td>
</tr>
<tr>
<td>Faecal streptococci (Enterococci)</td>
<td>1 logarithmic unit</td>
</tr>
<tr>
<td>Faecal coliforms (<em>Escherichia coli</em>)</td>
<td>100% of the MAV</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>100% of the MAV</td>
</tr>
<tr>
<td>Enteric parasites</td>
<td>100% of the MAV</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>100% of the MAV</td>
</tr>
<tr>
<td>Turbidity</td>
<td>100 % of the MAV</td>
</tr>
</tbody>
</table>

To flush toilets the requirements in Table 3 should be considered, where the values for total coliforms and faecal coliforms are defined as in the quality standards for interior bathing waters, under the terms of the national legislation and applicable European Directives (Directive No. 2006/7/EC of the European Parliament and the Council).
In Table 3, MAV and MRV mean, respectively, Maximum Admissible Value and Maximum Recommended Value, as usual.

Additional safety measures may be considered, such as the placement of signs requiring the closing of the toilet lid in the case of the flushing of toilets.

The requirements indicated in Table 3 are also applicable to the washing of clothes, which should not be carried out at temperatures less than 55º C.

For the watering of private gardens, the requirements given in Table 4 must be complied with, without the need for adding chemical products.

In the case of irrigation of products that can be eaten raw, the MAV indicated in the Portuguese Standard NP 4434 [6] must be considered, and is not recommend the use of grey water from kitchens.
For reference methods of analysis of the parameters mentioned in this specification, should be considered the methods listed in the Portuguese and European legislation on water quality and the number of tests should be set out in Table 5.

The start-up phase must have a minimum duration of 6 weeks and will only be considered finalized when, for each parameter, conformity in $X$ successive tests is seen (Table 5). During start-up period, the tests cannot be done with intervals of less than 7 days and the first test should only be carried out two weeks after the start-up of the installation.

After a prolonged stoppage or the detection of a serious problem in the installation, the restoration of its operation can be done only once verification has been carried out on the compliance with all parameters in $Y$ successive tests (Table 5).

The installer is responsible for the analysis during the start-up phase or that resulting from the stopping of the system caused by problems identified during the guarantee period (minimum 2 years). The compliance must meet the values in Tables 3 and/or 4, depending on uses, and without considering the tolerances indicated in Table 2.

The values indicated in Table 5, in the current operation column, correspond to the number of tests to be performed in a period of one year.

### Table 5 – Number of successive conforming tests in the various phases of the SPRAC

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Start-up period (value $X$)</th>
<th>After a prolonged stoppage or the detection of a serious problem (value $Y$)</th>
<th>Current operation</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Legionella</em> spp.</td>
<td>3</td>
<td>2</td>
<td>1 (summer sample)</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Faecal streptococci (<em>Enterococci</em>)</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Faecal coliforms (<em>Escherichia coli</em>)</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Enteric parasites</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Turbidity</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><em>Salmonellae</em></td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

If a deviation greater than that indicated in Table 2 in any of the parameters is detected, a revision of the installation must be carried out and the tests repeated within a maximum of 15 days (confirmation analysis). The procedure must be repeated on this frequency until they obtain compliance in all parameters.

If this is not verified within three successive confirmation tests, a serious problem should be considered and the installation stopped to detect and correct the anomalies.

The Safety Plan may impose more restrictive procedures than those mentioned above.
The tests to be carried out during the current operating period must be included in a installation maintenance contract.

5 Design of the systems and technical recommendations

In general, the need for regenerated water in residential buildings is considerably less than the quantity of grey water available, so it is not necessary to treat all of it but only the least polluted effluents, such as those from the shower, bath and sink.

An alternative supply of water to the SPRAC should be considered with water from other sources (supply), but with quality appropriate for uses intended. The operation should preferably be automatic and in the last stage of treatment.

When the minimum level of reclaimed water in the tank is reached, the supply device will start, introducing the amount of water required into the system.

Reclaimed water networks, including accessories, must be clearly differentiated from potable networks, suggesting the use of a purple pipe or colored tape, preferably with the warnings "Non-potable Network", "Non-potable water", "Reclaimed water" or equivalent, and whose state of repair must be regularly checked. Watering or washing devices, indoors or outdoors, must be marked with warnings similar to those mentioned above, together with appropriate symbols, and their taps fitted with detachable handles (security key) to prevent improper use.

One of the functions of the tanks is to compensate the gap between the affluence of grey water and its consumption, but may also have some influence on the quality of reclaimed water. Its volume depends on the habits of users, type of building, as well as processing time.

Generally speaking there is a balance between the production of grey water and regenerated water needs, so the reserve volume (before or after treatment) should not be larger than the average daily consumption.

There are water treatment technologies that can be used to treat grey water, with those that dispense with the addition of chemicals, requires little energy and economic maintenance being preferred. Among them we can refer to:
- Biological treatment systems;
- Membrane technology;
- Combined technologies.

If, along with the reduction of organic matter, there is also a microbiological reduction (which can happen with membranes or filters, for example) a particular stage for disinfection may not be necessary.

Several disinfection techniques can be considered, but the use of chlorine should be avoided because it can cause the formation of organic chlorine compounds, with possible adverse effects on the environment and public health. A common technique is ultra-violet radiation (UV), where, after the separation of solids and a biological treatment, a radiation of 250 J/m² is usually sufficient to ensure the necessary quality requirements.

The SPRAC installer must provide a plan of the executed system, the Maintenance Plan and analytical reports relating to the tests performed during the start-up period.

Inspections must be carried out according to manufacturer and installer instructions. In addition to verifying the operation of the components of the SPRAC and its overall operation, a test should be carried out on the odor and turbidity of the water.

There should be a maintenance contract with a certified installer or entity accredited by ANQIP for that purpose, whose presentation will be mandatory for the purposes of ANQIP Certification of the SPRAC.
Maintenance must meet the deadlines set by the manufacturers, in view of its proper operation, the increased lifespan and energy efficiency.

6 Conclusions

The efficient use of water is an environmental must for every country in the world. In the context of the 5R principle for efficient water use in buildings, the reuse and the recycling of grey water in buildings is one of the most important measures, which has great viability in residential buildings.

This is why ANQIP, a non-profit Portuguese NGO composed by companies and universities, decided to draw up a technical specification for Portugal (Technical Specification ANQIP ETA 0905), taking advantage of some of the experiences undertaken in this field in some countries and of some studies carried out recently in Portugal.

Particular attention was placed on public health aspects. The Portuguese specification requires that a safety plan is prepared and that periodical analytical checks are carried out.

For technical and public health reasons, the Technical Specification ETA 0905 also recommends that the systems are certified by ANQIP.

These initiatives will most certainly provide an answer to the increasing awareness about the need to promote rational water use in buildings, aiming to guarantee in a near future the essential sustainability conditions.

References


