The bathroom of the future: its contribution to sustainability

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Abstract

Introduction and aims: The exponential growth of the world’s population and, above all, the current model of economic growth based on an increasing consumption of resources, have placed the importance of environmental sustainability issues firmly on the agenda. Sustainability that may no longer be possible in today's world of almost 8 billion people on a planet of limited resources, according to some experts. A great deal of technical and scientific effort is currently focused on this issue. The use of resources and energy has to be ever more efficient and this efficiency must be sought at all levels, including, of course, buildings. The aim of this paper is to reflect on the part that the bathroom can play in this context in the future by contributing to the more efficient use of resources and energy, in particular through their recovery. Method: Taking into account energy and resources such as water and nutrients, the role of sanitary installations in their cycles or usage is examined, followed by a discussion of some perspectives for their recovery or improving the efficiency in their use. Results and conclusion: The bathroom of the future could play an important role in contributing to the overall sustainability of buildings and, in some respects, it may really help to solve the critical shortages beginning to become apparent in the case of some nutrients, such as phosphorus. Contributions: Specific proposals are presented for the design of future bathrooms as a vital contribution to environmental sustainability.

Keywords

Bathroom of the future; sustainability; efficiency; resources and energy.
1 Introduction

The world population has quadrupled in the last one hundred years, and the consumption of certain resources, such as oil, has increased a hundredfold... The exponential growth of the world’s population and, above all, the current model of economic growth based on an increasing consumption of resources, have placed the importance of environmental sustainability issues firmly on the agenda.

Sustainability that may no longer be possible in today’s world of almost 8 billion people on a planet of limited resources, according to some experts. Indeed, the global economic system consumes much more energy and resources than are actually available. The availability of fossil energies, for example, which amount to most of the energy consumed on the planet, is already in evident decline. With regard to water, about 40% of the world’s population lives now in areas of water stress and this figure will rise to 65% by 2025. Therefore, much technical and scientific effort is at present focused on the issue of the planet’s sustainability.

The natural sources of some mineral resources are already exhausted, as happened with cryolite (depleted in 1980, but its production was achieved by industrial processes). Others may run out physically or see their exploitation become economically unfeasible in the next 15 years. This is likely to happen for antimony, zinc, tin, lead, gold and silver and many others [1].

But there are very problematic resources such as water and phosphorus, the latter being essential to food security and for which the most pessimistic predictions of exhaustion vary from 20 to 30 years. There are also social consequences - perhaps the most tragic ones - because the poorest countries with a smaller voice on the world stage will certainly be the first to suffer from a shortage of resources, many of them essential to life. But even though some people will manage to survive to the predictable collapse of the global population, the current model of civilization cannot survive because it has stemmed from a period of abundant resources and will not endure long after their exhaustion.

Despite all this, the world seems unable to change the current consumerist model that props up economic growth. So, the short term solution will be to increase the efficient use of resources and energy at all levels and in all sectors, including buildings. This might prolong the current development model by using fewer resources and energy and/or promoting their recovery.
2 Water efficiency

Water has become a resource of the utmost importance. As already mentioned, demographic growth and, most especially, economic development and today’s lifestyles have rendered drinking water scarce and climate change is worsening the situation.

Policies for efficient water use are increasingly important and can be summarized by the 5Rs principle [2], also applicable to buildings:

- Reduce consumption
- Reduce loss and waste
- Reuse water
- Recycle water
- Resort to alternative sources

The first R – Reduce consumption, includes the adoption of efficient products and devices, without prejudice to other measures of an economic, fiscal or sociological nature. For this, labelling the water efficiency of products, as is done for energy efficiency, is considered an essential way to inform consumers.

The second R – Reduce loss and waste, may involve interventions such as monitoring loss in buildings (flushing cisterns, sprinklers, etc.) or the installation of circulation and return circuits of sanitary hot water. The re-use and recycling of wastewater, different from a "series" use or the re-introduction of water at the start of the circuit (after treatment), may be of interest for buildings, particularly in relation to the use of grey water. Naturally, this would not exclude the possibility of using wastewater for purposes such as watering gardens or even energy production (through biogas). The last R - Resort to alternative sources, may involve the use of rainwater, groundwater and even salt water. These measures can be easily taken on board for new buildings or refurbishment projects.

In Portugal, the issues relating to the efficient use of water in all sectors are becoming increasingly important, given the forecast of water stress in the short / medium term in most of the country. The certification and labelling of the water efficiency of products and the use of greywater and rainwater are important measures for buildings. They have been developed in Portugal on a voluntary basis by ANQIP (Portuguese Association for Quality in Building Installations), an NGO created to develop water efficiency in buildings that brings together universities, companies in the sector and water authorities.

The Portuguese water efficiency labels for products and the technical specifications issued by ANQIP for rainwater harvesting and greywater reuse in buildings were presented at previous meetings of the CIB W062 [2] [3] [4].
3 Recovery and reuse of resources

The recovery of minerals from wastewater is ever more important [5]. Recovery of phosphorous (P), for example, is at the top of world political priorities, as shown by the European Parliament statement of May 24, 2012 (§52) [6]. This provides for 100% P reuse in 2020 (“... draw up appropriated criteria and start pilot projects for several resources, for example P, with a view of archiving virtually 100% reuse by 2020 and optimizing their use and recycling...”).

Phosphorous is a unique non-renewable chemical element that is required for food production. About 90% of the world's P reserves are in China, USA, Russia and Morocco, where it has been estimated that today's recoverable reserves will be depleted within the next 30-40 years to 300-400 years. These estimations diverge due to the uncertainty regarding the volume and quality of the global reserves, and to the accuracy of estimates of future demand [7][8][9].

However, even if the reserves do last a long time, they will have increasingly negative environmental impacts. Its uniqueness therefore makes it urgent to develop new technological solutions to enable the recovery of and enable its reuse in the value chain. Population increase and the intensification of global agriculture will place increasing pressure on the finite supply of this resource.

The security of supply of agricultural fertilizers would provide a competitive advantage and a new way to recover P from water bodies would contribute to efficient resource management. In the last half century, P concentrations in freshwater and terrestrial systems have increased by at least 75% and the world's annual consumption of P fertilizer is estimated at 18 Mtons per year in 2007 [8][10][11].

On the other hand, this rejection of domestic and industrial effluents rich in P and fertilizers leaching into water bodies is the major cause of eutrophication, which is probably the most significant unsolved problem in terms of water resources protection. More than 50% of lakes are eutrophic and this is the main pressure responsible for the failure of the aim of “good status” by 2015 prescribed by the EU Water Framework Directive (EEA, 2010). Recent unofficial reports confirm that diffuse pollution is the main problem in European freshwaters [12][13].

Although the recovery of phosphorus constitutes an emergency in view of the security of food supply in Europe and pollution problems, its elimination through urine is one of the principal causes for the loss of the value chain. An average adult excretes about 1 g of phosphorus per day through urine excretion and as yet no systems are in operation for its recovery from aquatic systems or in urban wastewater treatment plants. The recovery of phosphorus in wastewater treatment plants is theoretically possible, but recovery at source, i.e., in buildings, would have numerous advantages by reducing the load on the treatment plant, avoiding dilution and minimizing the costs and energy consumption in the process.
In fact, most of the nutrients evacuated by man are found in the urine. Hence, using urine directly for agricultural purposes has already been the subject of pilot projects in South Africa, China, Germany and Sweden. China has installed more than 700 000 urine diverting toilets since 1998 and in Germany already has some buildings with this technology. In Sweden, the separation of urine is increasingly regarded as a solution for rural villages to reduce the nutrient enrichment of natural water lines, and there are now over 135 000 urine diverting toilets, as well as specific recommendations for the use of urine collected in buildings [14].

In the Netherlands, Waternet, Amsterdam’s water authority, has developed a pilot program for gathering and storing urine in public toilets since it is used for fertilizing public gardens and green roofs. It is estimated that a urine processing plant under construction in Amsterdam may eventually produce 1000 tonnes of fertilizer per year.

At present efforts are mainly focused on the recovery and subsequent direct use of urine as fertilizer, but the recovery of phosphorous at source (buildings) seems the most appropriate way to avoid the loss of this essential chemical element and there are already solutions that make this feasible. An innovative technology is being developed. It is based on a physical separation process using nanotechnology structures of alumina which induce nanoconfiguration and it is being used to recover phosphorus with high efficiency and subsequent phosphorus reuse [15][16].

The separation of urine in buildings, with or without recovery of phosphorus, requires a revolution in our bathrooms: urine separation toilets (Figures 1 and 2) urinals for residential buildings (Figure 3) and their generalization to females (Figures 4 and 5), new design for the installations, new rules of design, etc. Recent types of urinals for women have been presented at a previous edition of Symposium CIB W062 [22].

Figure 1: Separating toilet [17]
Furthermore, there is also potential for using urine or nutrients in the buildings themselves, on green roofs or urban agriculture, thereby boosting these two trends, which are now recognized as being of great importance in terms of sustainability policies. As a partner in the European Innovation Partnership on Water, ANQIP is leading the establishment of an Action Group in Europe in this area. Eleven partners are currently involved (companies, universities and associations) from four countries (Portugal, Spain, Slovakia and Turkey), including the Technical University of Kosice, from Slovakia, and two of the world's largest manufacturers of sanitary ware (ROCA, from Spain, and VITRA, from Turkey).

Figure 2: Separating toilet [18]

Figure 3: Urinal for residential buildings [19]
4 The water-energy nexus

Water and energy are two interdependent resources. Hydropower generation requires large volumes of water and the water supply and drainage systems in buildings and public networks require high amounts of energy.

The United States, for example, uses at a minimum the equivalent of 520 billion kilowatt hours per year - equivalent to 13% of the nation's total electricity use - to pump, heat and treat water. This is double the amount generated by all of the nation's hydroelectric dams in an average year and equal to the output of over 150 typical coal-fired power plants [23].
It thus becomes clear that an important contribution to energy efficiency can come from water efficiency measures, although this aspect is often overlooked in policies for efficient use of energy that are too focused on sectoral measures alone. In fact, water efficiency in buildings has a significant impact on energy efficiency, not only in the buildings themselves by reducing the need for water heating and pressurization, but also in the mains water supply and drainage networks by reducing the flows abstracted, pumped and treated.

In Portugal, where water and energy are two critical resources and both must be managed very efficiently, this nexus between water and energy is of particular importance. In terms of buildings, the Portuguese Regulation of Energy Performance in Residential Buildings already includes water efficiency as a possible contribution to energy efficiency, emphasizing the installation of showers with water efficiency labelling class A, A+ and A++.

A recent study by ANQIP within the municipality of Aveiro, showed that water consumption could potentially be reduced by $2.24 \times 10^6$ m$^3$ per year through water efficiency measures in buildings, which could result in a reduction of about $11.6 \times 10^6$ kWh per year, only in relation to the amount of energy needed to produce sanitary hot water. To this figure must be added the corresponding reduction of energy consumed by mains water supply and drainage networks and by treatment plants (by cutting the flows abstracted, treated and pumped), which was calculated at $4.4 \times 10^6$ kWh per year, thus totalling a potential decrease in energy consumption exceeding $16 \times 10^6$ kWh per year. The corresponding decrease in greenhouse gas emission, mainly CO$_2$, is 4500 tonnes per year [24].

The reuse of greywater in buildings is one of the 5Rs of water efficiency, as emphasized above. Assuming that the devices installed in a house are at least water efficiency class A, the average water consumption in Portugal can be estimated at about 100 L/(inhab.day) with a production of greywater close to 70 L/(inhab.day). This allows a potential for reuse of about 48 L/(inhab.day), of which 25 to 35 L/(inhab.day) can be used to flush cisterns and the rest for cleaning, watering, etc. In shared use buildings, where the use of showers is significant (student residences, public pools, etc.), the potential for greywater reuse may be more meaningful.

There are two basic systems for reusing greywater: short retention time and long retention time. The first generally applies to small compact installations such as ROCA W+W (Figure 6), where the greywater has a relatively short storage period and complex treatment is not needed. The second includes facilities for collective use, where the collection of greywater is centralized and retention times can be significant, and so additional treatment is required (Figure 7).
With regard to the water-energy nexus in the reuse of greywater, we can say that the compact installations also reflect a saving in energy, since reducing consumption in the building also corresponds to lower energy consumption in the urban water cycle.

With regard to large installations, with the "conventional" treatment for this type of water we find that the energy consumed in the treatment makes the system "neutral" from an energy standpoint, i.e. the energy expended in the treatment of greywater, about
1.8 kWh/m³, is equivalent to the energy saved in the urban water cycle. However, since the temperature of greywater from showers, for example, is generally above 30 °C, the utilization of this thermal energy for pre-heating hot water will allow a saving of about 3 kWh/m³, making these installations clearly advantageous not only from the point of view of saving water, but also from an energy standpoint.

5 Conclusions

Sustainability has become a key concept in modern times because of the world’s exponential population growth and the current model of economic growth, based on an increasing consumption of resources.

In buildings, the bathroom can make a very important contribution by allowing a more efficient use of water, the recovery of some critical resources such as phosphorus, and significant energy savings through the water-energy nexus.

However, the demand for this new role for the bathroom of the future will require rethinking the design of installations and the design criteria and developing new types of products and systems. This means a significant innovation effort from the technical and scientific community over the next few years.

6 References


17. http://www.cyclifier.org/project/urine-separation-and/


7 Presentation of the Author

Armando Silva-Afonso is a retired Professor of the University of Aveiro (Portugal), Department of Civil Engineering, where he still collaborates as Visiting Professor. His specialization is urban and building hydraulics and he is the President of the Board of ANQIP - Portuguese Association for Quality in Building Installations.