SCHOOL-INDUSTRY INTEGRATION IN CONTINUING ENGINEERING EDUCATION: A case study on green building research

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Abstract — *Water is, probably, the natural resource that will mostly constrain the human kind's freedom to develop within the foreseeable future. This truth is particularly noticed in the urban environment of the fast-growing megalopolis so common in developing countries – as it is the case of São Paulo, Brazil. This study shows the results of the integrated post-graduate research project of a Mackenzie Presbyterian University student, at the Engineering School, under the extended education program known as "Excellence in Civil Engineering Construction". Toilet flushing and garden irrigation spend much more water than all other edifice activities. A green project was developed in São Paulo by a building company, with the student's participation, with the objective of promoting total independence from the public water supply in what concerns to those two particular needs over a considerable part of the building. The case-study technical and educational results are reported in the paper.*

Index Terms — Water re-use, Building-water supply, Sustainable systems.

INTRODUCTION

Water reuse is defined as the use of wastewater (or served water) of a quality level under that found in most natural water sources [2]. Wastewaters are liquid disposals, generated by human activities, which have as a preferential destination the sewers (sewage collection network). Techniques for its reuse encompass from the simple recycling of used, non-drinking water, to the highest degrees of pollutant removal previously to the use of such waters, for more specific uses [5].

The level of quality needed for reuse is directly related to the type of use intended. So, the results obtained from effluent analyses must fulfil minimum requirements imposed by the legislation, so that each type of water utilisation may be allowed under proper conditions – according to the determination of norms as, for instance, NBR 13.969/97, by ABNT, in Brazil [1]. So, water quality control also comes into action, aiming at the fulfilment of each condition necessary to provide water compliance to acceptability limits, related to the presence of each relevant water pollutant, before use is allowed – accordingly to each specific application of the water resource. Whenever the available water quality does not comply with a specific need, treatment of a certain degree will, then, be necessary.

There are several, alternative types of wastewater 'sources' to be exploited by reuse. In terms of in-building circulating water, the several categories of water are: grey waters, rain water and drainage water.

Grey waters are the effluents of human domestic activities except the contributions of toilet flushes, i.e., containing only the waters disposed by baths, showers, toilet sinks, washing machines, kitchen basins and floor washing – mainly from homes and offices.

Rain waters are those originated by the surface flow due to rainfall, after collected by roof surfaces, shed tops for different uses, or, also, large, impermeable surfaces.

Drainage waters are those originated by rainfall collection from inside private land plots or from public areas served by surface drainage systems, as well as the collection of water poured from contention-wall drains (underground water resurfaced) or roof water discharged onto areas served by surface drainage systems.

The Brazilian Association for Technical Standards stated (in 1997), in the NBR 13.969 [1], that the degree of treatment required for the multiple use of water with components present in treated wastewater be defined, in general, by the most restraining use – in terms of required quality – being it so classified: class 1, considering direct contact with the user (e.g.: car washing); class 2, specifically for floor or pavement washing and garden irrigation, and class 3, relative to the reuse in toilet flushing. Because of such differences, storage systems in buildings must be identified by class, for security, as well as a user manual must be provided to guide operation and team training; also, periodic sampling of the water supplied to users must be demanded, and its analysis applied for the evaluation of the performance of the treatment system installed.

The project reported here aims, in general, at identifying the characteristics of water for reuse and evaluating its economic importance in the development of sustainability – so, contributing for the dissemination of the concepts and practice of rational water use through reuse. Beside this general objective, there are also specific objectives, such as: (i) contribute for the implementation of in-building reuse systems for non-potable purposes, showing to entrepreneurs and users the benefits of investing in such treatment facilities; (ii) identify the types of reuse most adopted in commercial buildings, in accordance to the standards; (iii) recognise the types of treatment employed; (iv) evaluate the importance of system maintenance, and (v) develop a case study in order to demonstrate the advantages of

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water reuse in a commercial building located in São Paulo city, Brazil.

LITERATURE REVIEW ON WATER USE AND AVAILABILITY

According to the United Nations Organisation World Resources Institute [9], in 1999, all the fresh water on Earth used to cover 2,5% of the total water surface of the Planet; however, only 0,007% being reachable, in technical-economic terms, for use by the human kind. From the overall water amount abstracted for human use, as much as 8% were used only in homes and offices – thus, demonstrating the importance of the potential for residential and commerce water reuse.

Under such a scenario, the perspectives for the next years indicate water shortage to become a reality until the year 2050, as detailed on Table 1.

TABLE 1
WATER SHORTAGE IN THE WORLD

Previewed population or supply conditions	Date: 2050
Total population	9,4 billion people
Population under supply sufficiency	58%
Population under supply insufficiency	24%
Population under supply shortage	18%

Source: World Resources Institute [9]

Apart from this, there is also wasting, as well as inefficiency, in the use of water and in the collection and treatment of residual waters – without mentioning the inefficiency and inappropriate measures in the disposal of non-treated wastewater. This is verified, for instance, in Brazil, where the Basic Sanitation Research Programme-2005 [4] shows sanitary a wastewater collection system that serves only circa 40,12% of the urban population.

In such a scenario, wastewater reuse appears, therefore, as an advantageous practice, which may also reduce the amount of wastewater disposed into the collection network (sewers) – since, by this means, part of the wastewater is treated and reused, instead of being just discharged into those collectors.

Apart from the problems mentioned above, under the absence of a national politics for the rational and sustainable use of water resources, according to data from the Brazilian Institute of Geography and Statistics-IBGE [6], in 2005 the Brazilian sanitation companies lost, in the average, more than 40% of the drinking water produced along the distribution process, through leakage from the supply distribution network. In the specific case of the São Paulo State Basic Sanitation Co., SABESP [4], the losses reported in 2006 reached 24% of the total water flow available for distribution. Such a water wasting rate represents 10m³/s, what is equivalent to supplying about three million people. If water reuse politics are implemented, important drinking water volumes would be saved from wasting: water of a lower quality, though sufficient for non-drinking uses (generally secondary effluents after some partial treatment), would be supplied for use in activities that can be developed with non-potable water.

Table 2 shows the difference between drinking and non-drinking water consumption per capita rates in commercial and residential buildings, both for the cases were alternative, water saving measures are applied and those where such measures are not taken.

TABLE 2
CONSUMPTION RATES IN COMMERCIAL BUILDINGS

Type of Building	Rate of non-drinking water reuse considering water saving measures in the building * (L/person/day)	Rate of non-drinking water reuse considering no water saving measures in the building** (L/person/day)
Commercial	40	80
Residential	150	300

Sources: * SABESP [4]
** MacIntyre [7]

METODOLOGY

The post-graduate research project which generated the summary constituted by this paper analyses an enterprise in São Paulo city, Brazil, where a water reuse system was implemented in combination to the use of rainfall: the commercial building called Eldorado Business Tower. The project was carried out and built by Gafisa Building Co., and, according to it, the system for water reuse is analysed and specified, showing the project characteristics and the complete abstraction, as well as the wastewater-recycling-and-treatment, and rain-water sub-systems. The volumes of water reservation needed for the system to support the oscillations in wastewater availability and in the rainfall natural rates are also defined in the project, as well as the type of technology applied.

On the basis of the alternative types of systems suitable for use, one may get informed (in much further detail) in the academic dissertation of 2009 which generated this paper (by the second author [8]) on the kinds of systems of higher efficiency for reaching the purposes proposed here, in technical and environmental terms – through a listing of positive aspects of each kind of system considered.

It is also shown in the dissertation that the type of treatment system finally selected for the project studied here is developed by the designer for the non-drinking reuse of the building grey wastewater – as well as the viability of the implementation of such systems in the enterprise is demonstrated there.

Whenever such a reuse systems is implemented in a building, one must previously define the values of: the average water consumption rate per person, according to the specific type of use of the building (either residential or commercial); the average percentages of consumption for each kind of activity; the price of the water charges to users by the local

supplying company; the possible, applicable types of treatment.

The analyses of the several treatment methods depend on the retention rates; on the method efficiency and on the characteristics of each kind of use. Also the costs related to the maintenance of the system adopted were analysed, including the quantity of drinking water to be saved in the overall enterprise due to the implementation of this alternative means of water supply.

CASE STUDY

In the Eldorado Business Tower project, a solution was chosen for reusing grey waters combined to rain water and to the liquid effluent discharged from the air conditioning system. The storage facilities designed for the regulation of time oscillations in water availability are lower reservoirs – to be better detailed further in this text. The grey wastewater undergoes simple filtering before being used for garden irrigation, as well as for toilet flushing on the ground floor. The whole system complies to the rules established by the Green Building Council – so having obtained the environmental certification "Leed", by that Council – according to information provided by the Sanitary Engineering design company responsible by the system installed, Acqua Brasilis [3].

Part of the total volume of rain water collected (the part in excess to the needs of the building operation and maintenance) is still discharged into the public drainage collection network. However, it was estimated by the system designers that the other part of the rainwater – that conveyed into the building supply system – contains, in the overall time average, 80% of the suspended solids that would, otherwise, be deposited onto the bottom of the public drainage collection system, so reducing its flow capacity end, probably, causing difficulties during storm drainage, such as local flooding in the urban area. With the existence of this rain water supply system, those solids will, instead, be separated from the liquid phase by treatment in the building and, therefore, receive a proper, environmentally convenient destination.

The system for separation of suspended solids from the rain water is constituted by the civil structures, on the one hand, and by equipment, on the other hand. The latter was imported from factories in the USA. For its installation at the proper, intermediate point along the treatment process (as defined by the system designers, Gafisa Building Company), an inspection well was built under the ground with internal diameter of 1,20m. It is provided with a manhole for access and, on its bottom, the equipment for suspended solid segregation was fixed (more details can be found in [8].

The complete treatment system is installed on the third (and lowest) underground floor, occupying an area of approximately 40m² (only 0,2% of the total dwellings area). Circa 99% of its activities are automatic – it is possible to say that only filter maintenance (basically, filter replacement) and chlorine supplying were left, in practice, for manual operation.

This system, adopted and designed by Acqua Brasilis [3], works in the way described as follows. The rain water is collected and conveyed into one of three reservoirs, specifically for this purpose. The other two reservoirs have, each one, its specific purpose: one is meant for the storage of ground water, as well as for the water from the air conditioning system (both used for complementing supply needs, very rarely – as, for instance, during long droughts or whenever the dwellers are massively out, e.g., during holidays), and the second one is meant for storing the water already treated by the system (therefore, ready for reuse).

The installed capacity for rainwater storage, allied to the considerable potential of the ground water source (such as to continuously complement the water needs), are enough for supporting, together, the maintenance of the building for the purposes served by reuse water and rain water for up to thirty dry days.

Of course, part of the rainfall water dropping inside the Eldorado Business Tower premises is lost for the purpose of storage (particularly, a great part of storm water falls, due to the limitation of the storage facilities). It could be estimated by the designers that only circa 10% of the water falling inside the rainfall collection area of those premises (a total area of 2500m²) will be used by the combined supply system.

Tables 3 and 4 list the main characteristics of the Eldorado Business Tower building and premises.

TABLE 3
CHARACTERÍSTICS OF THE ELDORADO BUSINESS TOWER

Total land area occupied: 19.000 m²
1 tower of 32 floors
1 to 2 units per floor
Private area per floor: 2000 m²
WC facilities per floor: 1 female and 1 male (each internally divided)
Average number of inhabitants per floor: 285 (based on the rate of 1person/7m² – used for estimating water demand)
Total number of inhabitants: 9.120
Average water consumption rate: 50 L/person/day (base: information given by the representative of the designers – see [8])

Source: Acqua Brasilis [3]

TABLE 4
ELDORADO BUSINESS TOWER RESERVOIR DIMENSIONS

Item	Capacity (m³)
Rain water reservoir	69,24
Ground and air-conditioning water reservoir	105,09
Treated water reservoir	99,7

Source: Acqua Brasilis [3]

TABLE 5
SYSTEM IMPLEMENTATION COSTS
ELDORADO BUSINESS TOWER COMBINED WATER REUSE

Item	Costs (R$)
Total costs of the treatment system for rain, ground and air conditioning water	77.600,00
Cost of the system for the automation of the rain water treatment	19.292,00

Source: Acqua Brasilis [3]

The costs of the treatment systems and of the automation of the rain water collection system are shown in Table 5. The costs of the installation of this combined, alternative system for water supply can be divided into 30% for labour and 70% for materials.

ANALYSIS OF THE RESULTS

From the main data and results extracted from the complete research project, summarised in the text above, it is possible to establish comparative results showing the advantages of water reuse in the Eldorado Business Tower.

The water treatment system, whose cost amounted to R$96.900,00, approximately, presented relevant positive results, such as:

a) The use of rain water and the reuse of wastewater for garden irrigation and for toilet flushing yielded the benefit of saving 50% in the whole water bill – when compared to the alternative of buying drinking-quality water for all building uses. This is consistent to the statistics on per capita human consumption of drinking water in commercial buildings: 40L/person/day – since the rate without economical, alternative supply measures is reported as being 80L/person/day and the respective rate without economy, as half this figure – as shown on Table 2.
b) The direct reuse of grey waters for toilet flushing and garden irrigation just after treatment, without the allocation of area for treated water storage facilities – not necessary for this commercial building, where most of the water needs are concentrated in the circulation area (ground floor, for instance) – allows for a more economical use of land and the reduction of the capital costs for system implementation. In the case of this particular system, only 0,2% of the total dwelling area was necessary for its implementation.
c) The system automation provided in this case favours the optimisation of man power application, consequently promoting cost reduction in the overall system operation. This could grant considerably low system maintenance costs for the owners, or tenants, occupying the building.
d) Low costs resulted for the implementation of the used water treatment system, considering that the total enterprise cost was R$ 180.000.000,00 – in fact, the system cost amounted to R$ 96.892,00, equivalent to 0,05% of that total cost, only.

CONCLUSION

All the results and specific analyses above allow to conclude that the reuse of waters in buildings can be much befitting in terms of reducing operation and maintenance costs during their life spans. According to the specific results from the analysis performed in this case study, it became evident that such a system is economically viable in commercial buildings, as an alternative to the conventional supplying systems, based on the use of potable water for all purposes.

The effluents of human hygiene activities known as grey waters, after collection and appropriated treatment, can be considered, in civil works, as an alternative source of water supply that, besides demonstrating economically advantageous for the user-payer, bear also the advantage of saving the more and more scarce water sources of the Planet – so, contributing to sustainability, before the enormous problem of increasing water shortage faced by the human kind.

The minimum requirements to be claimed for the implementation and utilisation of such systems, considering all sorts of water application, are the subject of technical standards, legislation, resolutions and other provisions from the regulatory power – be it the government or technical boards. This has been consistently demonstrating the importance of this theme, as well as the consequently increasing level of attention to it.

The case study presented here led to the conclusion that the implementation of such systems in commercial buildings offers a great potential of alternative water supply, as well as of economic viability – with the possibility of relevant cost-benefit gains.

Moreover, these systems do not demand considerable operation and maintenance expenditures – since most of the process is automatic – as well as it bears accessible costs when compared to the overall building costs of these commercial dwelling facilities.

Beside the low implementation and maintenance costs, the proposals in this article include also an issue of growing environmental importance: the economy of drinking water sources, which imply the reduction of future problem and expenditures for house owners and the human kind in general.

Another important conclusion resulting from this literature review and case study was the importance of the architectural aspects during the design process. In fact, developing the ideal lay out for housing the reuse plant in the building area is not an easy task, particularly in the exiguous areas available due to the compact land occupation of any modern metropolis. This technical problem is obviously easier to solve during the design of new buildings, as opposed to the case of an pre-existing building under a modernisation process – due to the restrictions imposed by structural reasons, mainly. These are the main factors challenging building water-supply system designers, particularly in what concerns to the difficulty to insert several pipe networks, namely: a specific supply network for the reused water and the associated alternative sources (as rain water and air conditioning effluents) and a separate wastewater collection pipe system for the grey waters. So, an appropriate, optimised design of these sanitary building systems are fundamental to defend the adoption of water reuse systems as technical-economically advantageous.

For the reasons above, the dissemination of this approach to sanitary building design will only be broadly observed as more and more new buildings, or more cases of very comprehensive changes in pre-existing building lay outs, take place in important cities.

Meanwhile, it seams that, in the case of the construction of new buildings, modern projects aiming at building sustainability may no longer leave unconsidered the options for water reuse, rain water supply or the use of the other alternative sources, as exemplified in this case study.

As a consequence, the inclusion of the teaching of such matters in the university syllabuses of Engineering and Architecture courses must be faced as an adamant demand, for granting the proper formation of future professionals for the 'brave new world' of sustainable building practices.

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