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COMPARISON BETWEEN TWO CASES STUDY ON WATER KIOSKS

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Consumul de apă îmbuteliată aîinceput în Europaîinca din anii `70. Impactul asupra mediului cauzat de către linia de producție a apei îmbuteliate este însemnat: de exemplu folosirea sticlelor de plastic, consumul de petrol pentru producerea sticlelor, noxele emise în atmosfera de catre transportul sticlelor, ne-reciclarea ambalajelor de plastic, etc. Această cercetare prezintă o evaluare a impactului asupra mediului şi a celui economic pentru două studii de caz, în ceea ce priveşte kiosk-urile de apa, ce au scopul de a pune la dispozitia consumatorilor apa carbogazoasă şi ne-carbogazoasă cu proprietați organoleptice îmbunătățite în comparțtie cu apa de la sistemul public de alimentare.

Bottled water consumption in Europe began in the 70s. Environmental impact derived from water production chain is very significant: for example plastic bottles use, oil consumption for bottle production, air emission from vehicles transporting bottles, not recycled plastic packages, etc. In this research an environmental and economic impact evaluation was presented for two case studies, regarding water kiosk design with the aim of supplying controlled natural and sparkling water with better organoleptic quality compared to water directly supplied from aqueduct.

Keywords: water, water kiosk, environmental and economic balance.

1. Introduction

The consumption of bottled water in Europe began in the '70s and increases each day. The drinking bottled water, over the years, has become a status, then a practice, with massive growing investments on advertisement campaign. The perception of water changed from a basic and essential drink to a source of health and even beauty. The specific consumption of bottled water in Italy is the highest in the world, with 200 liters per capita in 2010 [1], steadily

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increasing, while in Romania an inhabitant consumed almost 60 liters of bottled water in 2010 [2]. The environmental impact resulting from the mineral water industry is important and significant, with respect to plastics fraction found in municipal solid wastes [3,4] and their treatment methods [5,6]. Each stage of the bottle life (production, transportation, disposal), involves a significant impact on the quality of the environment.

In particular, regarding the Italian situation:

- 350,000 t_{PET} of Polyethylene terephthalate (PET) were used in 2008 to produce plastic bottles necessary to bottle about 12 billion liters of mineral water, with a consumption of 665,000 t of oil and emission of about 910,000 t_{CO2} equivalent (calculated using the emission factor of 2.6 kg_{CO2} per kg of produced PET) [7];
- the transportation of mineral water has a considerable influence on air quality, only the 18% of the total amount of bottles freight travels using rail network, [8];
- about one-third of used plastic bottles are collected separately and forwarded to recycling.

This situation can be faced considering the need to reduce the environmental impact and avoiding doing the same errors in the developing countries where, for different reasons such behaviors are not so consolidated.

A simple solution which could be adopted implies that consumers drink water supplied by public aqueduct. This will lead to considerable technical, environmental and economic advantages for the single consumer and for all the community. For this reason municipalities are moving towards the promotion of "water kiosks" or "water houses", enhancing the use of drinking water and spreading eco-sustainable behaviors, hence reducing waste production at source. These structures are located in strategic positions, and provide the public with withdrawal points of drinking water, and in particular:

- water with improved organoleptic characteristics compared to tap water supplied directly from the public aqueduct;
- water supplied both carbonated (sparkling) or non-carbonated and chilled or at room temperature.

2. Materials and methods

In this paper is reported an experience developed and conducted in Italy. The balances and the calculations regarding the environmental impact have been done also in a hypothetical application of this solution in a Romanian town having almost the same dimension as the Italian one.

The case study (Fig. 1) presents a kiosk with a rectangular plan (3.30 x 3.00), height 2.50 m, having three external walls equipped with dispensers of drinking water, two for sparkling water and one for the natural one; the fourth side is provided with an entrance for maintenance operations and equipment loading and unloading.

The public aqueduct supplies the kiosk with water. The inflow water passes through filters (activated carbons); the outgoing natural water is sent to the dispenser for the distribution of “normal cold water”, while the water allocated to providers for “sparkling cold water” undergoes a process of gassing.

The sampling line from the aqueduct is composed of a pressure regulator with pressure valve. The water passes through a filter that removes the substances in suspension and chlorine, also reducing the presence of any eventual by-products and other types of micro pollutants. The outlet of natural water is preceded by a battery of UV rays filters. Part of the water is sent to a device with functions of providing chilled and carbonated water. A pump draws the water from the tank of the ice bank and pumps it in the recirculation pipe. The continuous flow of water allows maintaining a low temperature in the line connecting the cooler with the delivery points. The unit is connected to a CO_2 cylinder. Every night a cycle of sanitization of the pipes runs to prevent the bacterial regrowth, with a stabilized solution based on hydrogen and silver peroxides. The water kiosk is equipped with a remote control system, so that workers can intervene in case of failures, sudden problems, as well as for the replacement of gas cylinders and replacement of filters.

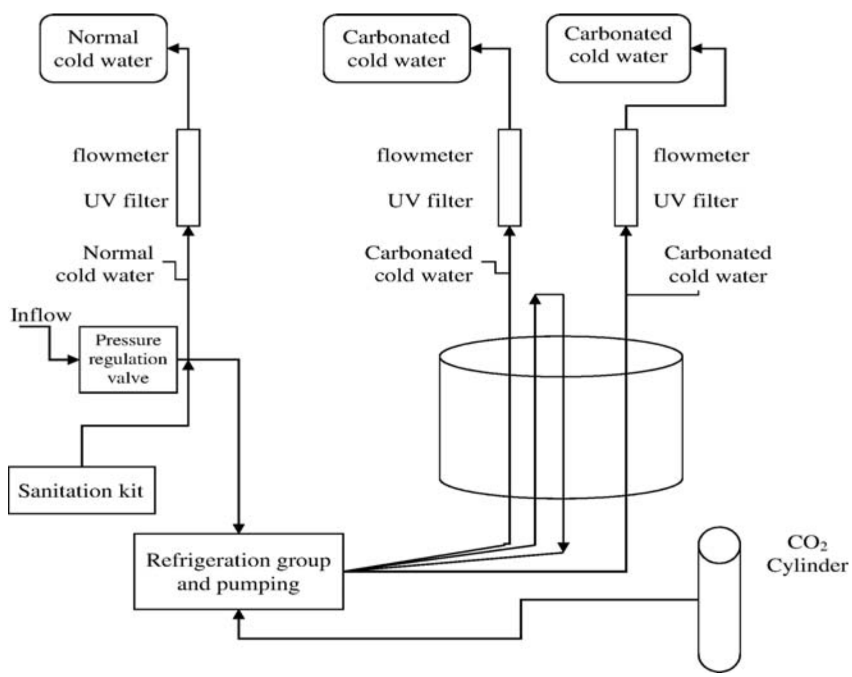

Fig. 1. Scheme of the plant

3. Results and discussion

The study presents the possibility of placing a water kiosk in a small town of about 9,000 inhabitants, with respect to Italian and Romanian cases. Table 1 shows a considerable saving of plastic bottles (volume of 1.5 L), with a consequent saving of PET and the related oil necessary to produce it (considering 30 g_{PET}/bottle, and 1.87 kg of oil consumption per kg_{PET} [9]).

Another important aspect is related to the lack of need to transport water, since the use of the public dispensers ensures the availability of "zero km". Considering that the total amount of yearly supplied water by kiosk is about 1.856 m^3 $year^{-1}$, corresponding to 1,237,067 bottles 1.5 L, and assuming that: the corresponding quantity of water in bottles should be transported by road, the mean path to be covered by transportation is 250 km for the Italian case and 350 km for the Romanian case are presented in Table 2 (with a specific consumption of diesel fuel equal to 5 L km^{-1}) and the quantity of bottles transportable by one truck is about 10,000 bottles per trip, it results consumption of diesel of about 6,185 L for Italy and 8,660 L for the transport of water bottles in Romania.

Table 1

Savings

Parameter	Quantity
Number of 1.5 L plastic bottles	1,237,067
PET (for the production of bottles 1.5 L) [kg]	37,112
Oil for production of bottles [kg]	69,399
Diesel for transportation - Italy [L]	6,185
Diesel for transportation - Romania [L]	8,660

It is interesting to set an environmental balance in terms CO_2 emission, using the conversion factors reported in the technical literature; the correct balance can be obtained considering also the energy consumption for the system operation (Table 2).

Table 2

Environmental balance: yearly CO_2 emission

Item	Quantity	Conversion factor
Not emitted CO_2 (bottles production) [kg]	96,491	2.6 kg_{CO2} per kg_{PET} [5]
Not emitted CO_2 (transportation) [kg]	16,178	2.6391 kg_{CO2} L^{-1} [8]
Emitted CO_2 for energy consumption [kg]	6,027	0.5405 kg_{CO2} kWh^{-1} [8]

Similar considerations can be made for other pollutants: considering the same handled quantities, there is a minimization of annual emission by vehicular traffic of about 40 kg_{CO} and 85 kg_{NOx} for Italian situation and about 56 kg_{CO} and 120 kg_{NOx} for the Romanian one [10,11].

The mean path to be covered by transportation of water bottles (Fig. 2) from the production site to the main Italian cities is approximated to 250 km, determined considering the distances to be covered by products of some of the most popular Italian brands from the springs (or production site) to the six main urban centers. The same calculation was made for the Romanian case (Fig. 2) choosing 5 main cities and assuming the overall distance from the water spring. The approximated distance was set to 350 km, significantly larger than in the Italian case, hence a higher diesel saving if the water kiosks solution is adopted.

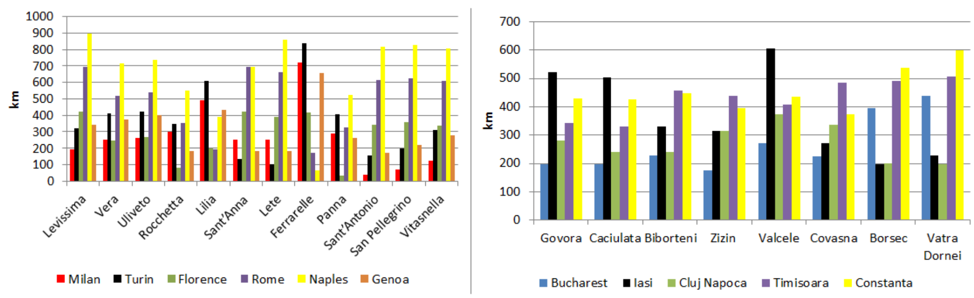

Fig. 2. Distance between springs and main Italian and Romanian cities

The environmental benefits are not always enough to convince consumers to change their habits and customs. At this point it can be useful a powerful incentive: the potential cost savings.

The average cost of natural and sparkling water on the Italian and also the Romanian market is the same, around 26 cent L^{-1}, as a result of an assessment conducted in large distribution centers (cost of carbonated water: average 25 cents L^{-1}; natural water: 27 cents L^{-1}). The cost of water delivered to consumers by water kiosks is zero for natural water and 5 cents L^{-1} for sparkling water. Clearly there is a very significant economic saving, corresponding to about 53 € inh^{-1} $year^{-1}$ (Table 3).

Table 3

Economic savings based on the liters of water supplied by the water kiosk in a year

Volume of natural water supplied [L]	Volume of carbonated water supplied [L]	Cost for buying carbonated water (kiosk) [€]	Cost for bottled carbonated water [€]	Cost for bottled natural water [€]	Total saving [€]
925,200	930,400	46,520	241,904	240,552	435,936

Often local governments that use the water kiosks with promotional purposes do not require any payment from the customers (or a minimum fee for carbonated water). Moreover we consider correct to carry out an assessment, considering the real costs for the public administration, with the aim of establishing the fee that may be required from the community, in order to provide an economically sustainable public service.

Analyzing the management costs necessary for the correct running of the water kiosk, the items that require most attention are the costs related to the replacement or changing of the CO_2 cylinders, filters, UV lamps, electric energy supply and the maintenance operations (in particular cleaning). The costs for chemical analysis of water are not taken into account, assuming they are absorbed into the corresponding costs for the service of public aqueduct. The calculation of costs for the replacement of the cylinders of CO_2 requires the amount of carbonated water supplied. Referring to the two similar cases study:

- the water kiosk has 5 cylinders (30 kg each);
- gassing a liter of water requires an average quantity of 6 g_{CO2} (concentration: 5-7 g L^{-1}); The annual consumption results of approximately 90 cylinders (max 217 corresponding to 7 g_{CO2} L^{-1});
- the cost of 1 kg_{CO2} (including charges for transportation and contributions) is about 0.8€ in Italy (and 0.6€ in Romania);
- the cost for changing a single cylinder is about 3.2€ (2.8€ in Romania);
- the cost of one cylinders monthly rental is 1.5 €.

The cost of the filters is 67.50 €/each (60€ in Romania) considering a change every 5 m^3 of treated water (precautionary hypothesis), while the UV lamp (9 €/each) are replaced whenever they are out of order (estimating maximum twice a year for the 3 lines). With regard to the cost of maintenance, the more critical equipment is the carbonation devices. In fact all the other instruments (gearboxes, pressure pipes, electrical boards, counters, etc.) require only a minimal maintenance. So, the annual maintenance cost was assumed 15% of the cost of the device (the cost of each carbonation device is about 8,000 €). The evaluation of the cost of electricity supply of the kiosk has been made based on the bill of the energy supply company. Finally, the cost resulting from the automatic sanitizing cycle that runs every night, was assumed about 0.60 € per day. The last item necessary for cost estimation and economic balance, is amortization related to construction cost (civil works, electric and hydraulic plants, technical gasses, architectural solutions, urban design, lacing to aqueduct, electrical and sewage networks, etc.). The cost of building was about 68,000 € divided into the following items:

- civil works (structure and lacing to supply networks): 42,000 €;
- hydraulic works (including regulators, carbonation devices, general equipment, filters, etc.): 14,000 €;
- electrical systems (switchgears, electric board, etc.): 4,000 €;
- other technical costs (including design): 4,000 €;
- costs for finishing (painting and green area): 4,000 €.

An analysis of the return on investment considers the hypothesis of self-financing the intervention, considering to repay the used economic resources at an annual rate of 3.5%, and assuming a depreciation period of 10 years, both for civil works and electromechanical equipment. Making these considerations, we estimated an annual installment for Italy and Romania of about 8,100 € (Table 4).

Considering the total amount of supplied water by the kiosk and the total annual management cost, we obtained a specific cost respectively of less than 3 cent L^{-1} in the Italian case and around 2 cent L^{-1} for the Romanian one.

Table 4

Annual operating costs (values rounded to 1 Euro) in the Italian and Romanian case study.

Operative management	Item	Quantity	Unitary cost (Italy)	Unitary cost (Romania)	Annual cost Italy [€]	Annual cost Romania [€]
CO_2 cylinders	CO_2 supply	Carbonated water annual supply: 930,400 L				
		Max CO_2 consumption (calculated for 7 g_{CO2} L^{-1}): 6,513 kg	0.8 € kg^{-1}	0.6 € kg^{-1}	5,211	3,908
	Cylinder change	Number: 217	3.2 €/each	2.8 €/each	695	607
	Cylinder rental rate	Number: 5	18 €/each	15 €/each	90	75
Filters	Filter replacement	Annual water supply: 1,855,600 L				
		Number: 372	67.50 €/each	60 €/each	25,056	22,32
UV lamps	Lamps replacement	Number: 6	9 €/each	7.5 €/each	54	45
Electric energy		11,151 kWh	0.169 € kWh^{-1} including fixed costs	0.147 € kWh^{-1} including fixed costs	1,883	1,642
Maintenance					1,2	1
Automatic sanitizing			0.60 € per day^{-1}	0.50 € per day^{-1}	220	183
Chemical analysis					0	0
Depreciation installment					8,1	6,1
Total					42,51	34,88

6. Conclusions

In this study an environmental and economic impact evaluation has been presented with respect to water kiosk. The application regards a case study of a real water kiosk located in a town with 9,000 inhabitants, in the Northern part of Italy and a hypothetical one in a Southern region of Romania. After a running time of one year it was possible to make some environmental and economic balances.

The environmental benefits are clear and evident, in particular referring to reducing air emission (related to bottle transportation), fuel consumption, and oil consumption (necessary to produce PET bottles).

Another important aspect is the economic one, with a significant yearly reduction of cost for drinkable water supply. Moreover, with the aim of realizing a supply service suitable from an economic point of view, a calculation was done in order to determine a specific fee for water supply. We have obtained that a self-financing solution could be reached applying an average fee of around 3 cent L^{-1} in the Italian situation and around 2 cent in the Romanian one.

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