Estimating water consumption in nursery and elementary public schools

M. S. O. Ilha (1), O. M. Gonçalves (2), S. V. de Amorim (3); L. P. Pedroso (4)
(1) msoilha@fec.unicamp.br
(2) orestes.goncalves@poli.usp.br
(3) simar@power.ufscar.br
(4) luppedroso@yahoo.com.br
(1) Department of Architecture and Civil Construction Eng., Faculdade de Engenharia Civil, Arquitetura e Urbanismo, Universidade Estadual de Campinas, Brasil
(2) Civil Construction Department, Escola Politécnica, University of São Paulo, Brazil
(3) Department of Civil Engineering, Universidade Federal de São Carlos, Brasil
(4) Department of Architecture and Civil Construction Eng., Faculdade de Engenharia Civil, Arquitetura e Urbanismo, Universidade Estadual de Campinas, Brasil

Abstract
This paper presents the methodology and results of a study concerning estimation of water consumption developed in public school buildings which take into account the characteristics of the buildings as well as the water consumption indicator. These school buildings are located in the city of Campinas, state of Sao Paulo, Brazil, and the study was developed by a team of researchers from three universities of the State of Sao Paulo.

This study includes a survey of all plumbing fixture pathologies and their remote water consumption monitoring in a sample of schools which involves students of different age ranges and different periods in school. The adopted criteria to select the sample, the employed field data collection methodology and the results obtained are here presented. Finally, a model to estimate the water consumption in this type of building is also presented.

Keywords

Building systems, water consumption, schools, cold water building system.

1 Introduction

Water consumption in Brazilian buildings is usually estimated using a simple consumption indicator expressed by volume divided by consumer (persons in homes, students in schools, beds in hospitals, etc). In the case of school buildings, the values of water consumption indicator are 30 to 50 liters/student/day in a four hour period of school and 50 to 100 liters/student/day in the case of full day period.

However, to estimate water consumption, the characteristics of the building and the region where it is located besides the consumption indicator must be considered. In numbers, Brazil is a country with an area of about 8,514.876.599 km^2, with more than 5,507 cities, different climates and habits of its inhabitants, which affect, besides other aspects, the water consumption.

The Brazilian school system consists of private and public schools, both equivalents in years which include nursery school, elementary school, high school, graduate and undergraduate school.

Table 1: Public and Private Schools - Typologies

Public and Private Schools		Age	Period	Number of periods
Nursery school		three months to four years old	7am to 6pm	1
Pre-school*		three months to 6 years old		
Elementary school	kindergarten	four to six years old	five hours	
	fundamental school	seven to fourteen years old	four hours	3

*Pre-school is the combination of nursery and kindergarten.

Two typologies of pre-school were found:

- one that contains one kitchen to prepare the children's meal and a laundry for the nursery part of the school, and the staff who works to both schools.
- the other one contains two separated schools, each one with its own kitchen, own laundry, own staff and a bathroom exclusively for babies in the nursery unit. The principal and the janitor are the only part of the staff that is shared in this case.

Due to the high number of illiterate and semi-literate adult population in Brazil, there is a program for adult education which uses the public school buildings during the evening period that otherwise are used for nursery, elementary and fundamental education.

In 2000, 68.1% of the students in nursery and elementary schools, 89% of the students in fundamental schools and 78% of the students in high schools belonged to the public school system network. On the other side, in graduate schools, only one third of the students belong to the public education network (IBGE, 2005).

This paper presents an investigation that evaluates the water consumption in a sample of nursery and elementary public schools of the city of Campinas. This investigation includes a survey of all plumbing fixtures pathologies and remote water consumption monitoring in a sample of schools involving students of different age ranges and different school periods.

This study presents the adopted criteria to select the sample, the employed field data collection methodology, the results obtained and at last, the proposed model to estimate the water consumption in this type of building

2 Field Investigation and Results

2.1 Sample Selection

Campinas is a city located in the state of São Paulo, Brazil. Its area is about 797 km² and its population was approximately 967.921 inhabitants in 2000 (Cano&Brandão, 2002).
Although this research project had contemplated the four types of public schools, only the existing 122 units of nursery and elementary schools of Campinas in 2002 constitute the scope of this paper. Based on the water consumption indicator (average volume of water consumed per student in a month), geographic location and type of school, 73 units of nursery and elementary schools for this study (46.2% of the total), were selected. They were distributed as follows:

- 05 **CEMEI** (nursery school) - 71.4 % of the total of this type,
- 41 **EMEI** (kindergarten) - 64.1% of the total of this type,
- 03 **EMEI/FUMEC** (kindergarten with adult education in the evening period) – 50% of this type,
- 23 **CEMEI/EMEI** (pre-school) – 52.3% of this type,
- 01 **CEMEI/EMEI/FUMEC** (pre-school unit with adult education in the evening period) – the only unit of this type.

2.2 Building Characterization and survey of plumbing fixtures

The only documents found in the Municipal Department of Education were the site planning of all schools investigated and the architectural designs of some of these units. Due to the lack of building systems design an inventory of plumbing fixtures was necessary. Besides this inventory, leakage investigation and survey about the water usage were performed. It was also surveyed some variables that characterized the units and its site conditions, for instance, permeable and non-permeable outside areas, number of classrooms, bathrooms, type and number of plumbing fixtures and population.

Check lists were prepared to survey plumbing fixtures and existing leakage. Some lists were used to identify the location of each fixture, the conservation state (existence of spots, scratch, etc) and the operation condition (adequate, leaking, clogged, etc.).

For these analyses, the data surveyed were aggregated in four types of schools. So, the units with and without adults education in the evening period were considered included in the typology.

Regarding the site condition: nursery schools have lesser outside areas (non-permeable and permeable areas); regarding the number of rooms: Nursery and kindergarten units (CEMEI/EMEI) have the major number of rooms (classrooms, bathrooms); and regarding the number of fixtures: lavatory faucet and valve-operated water closet are the most frequent in number.

Concerning the population:

- CEMEI/EMEI units (pre-school) have the major number of students on part time in the day period,
- EMEI/FUMEC units (kindergarten/ adult's education), the daily population represents about 97.9% of the total population, in the CEMEI/EMEI/FUMEC unit (pre-school and adult education in the evening period) this value is approximately 98.7%, and
- CEMEI/EMEI units have greater populations.

The only information concerning the age of schools buildings was that the age range of 61 units varies from 4 to 62 years (base year: 2004).

Visual inspection and specific tests were used for leakage detection. The most frequent problem found in the fixtures was the leakage that occurs when faucets and valves are in operation. Concerning the conservation state, the most frequent problem was the existence of spots in the fixtures and lack of handles in valves.

The number of fixtures in non-conformity with the standards is large due mainly to the low price policy and consequent poor quality in public buildings. Poor maintenance in this type of buildings increases the problem.

From this investigation, a leakage rate (number of plumbing fixtures with leakage divided by total number of plumbing fixtures installed in the school) was calculated. The losses rate (relation between volume lost in leakage during a defined period of time and the total volume consumed in the school in the same period) was also estimated.

Results concerning the plumbing fixture leakage rate indicate that:

- 60.3% of the 58 schools with valve operated WC have leakage rate between 20% and 50%,
- 56.5% of 69 units have lavatory faucets leakage rate between 20 and 50%,
- Leakage rate of other type of faucets is low (more than 80% of the units have this rate equals to zero).

The major values of leakage rate are found in the fixtures that have direct contact with the students. Besides specification of durable components and implementation of

preventive maintenance routine, it is necessary to develop a general program for water conservation awareness in order to reduce the leakage rate.

Considering all plumbing fixtures installed in the surveyed units, it was verified that:

- CEMEI units (nurseries) had a leakage rate of 7.2% and standard deviation of 9.3%. EMEI units (kindergarten) had a leakage rate from zero to 21.4%, with the average equals to 6.8% and a standard deviation of 4.9%. CEMEI/EMEI units had a leakage rate between 1.3 and 15%, with an average of 6.8%;
- Considering that great values of the leakage rate do not always represent great volume of water, water loss rate must be taken into account. The water loss rate estimation can be obtained by means of metering the lost volumes or, when it is impossible, using reference volumes from bibliography;
- As there is no reference for the loss water volume that occurs only during the use of the appliance (most frequent problem found in all schools), this volume was not considered in the loss rate determination;
- In six surveyed schools leakage occurred in the pipe that supplied water to the upper reservoir. Part of this pipe is buried and a leakage in this region can represent a great loss of water due to the high pressure in the water public system. Water losses were estimated from 300 to 14400 liters/day. The lack of information about the consumption of these units do not enabled to estimate the leakage rate;
- The leakage rate of schools that do not have leakage in the supply pipe varied from zero to 60% (about 69.3% of the school had leakage rate between 10% and 20%).

2.3 Water usage

A questionnaire was applied to survey the water usage. The questionnaire concerned the manner that people use water in the bathroom, kitchen, floor cleaning, watering garden and vegetable garden, etc. Table 1 shows the distribution of interviewed in each type of schools investigated.

Table 2: Interviewed population (average).

School type	Percentage of interviewed	
	teachers	Other employers
CEMEI (nursery)	48.8	35.0
EMEI (kindergarten)	50.9	60.9
CEMEI/EMEI (nursery and pre-school)	31.8	33.7

Besides interviews, a field observation was made in three schools to determinate a typical water consumption day and to estimate a consumption distribution. The water consumption distribution in different activities was:

- CEMEI units: 45% in the bathroom, 43% in the kitchen, cafeteria, etc., 8% in the laundry and 4% in external spaces;
- EMEI units: 71% in the bathroom, 25% in the kitchen, cafeteria, etc… and 4% in external spaces;

– CEMEI/EMEI units: 86% in the bathroom, 10% in the kitchen, cafeteria, etc and 4% in external spaces.

Bathrooms are responsible by the major portion of the water consumption; kitchens are in the second place.

Based on this investigation about water usage, a methodology was developed to estimate the water conservation awareness rate (IU), whose description is showed in YWASHIMA (2005). Basically, number of "units" was assigned for each activity and the way how they were performed – rational or non-rational usage. So, the higher this rate, the greater is the users' perception for the rational use of water. Results of the assigned "units" are shown in figure 1 (see example for an EMEI building).

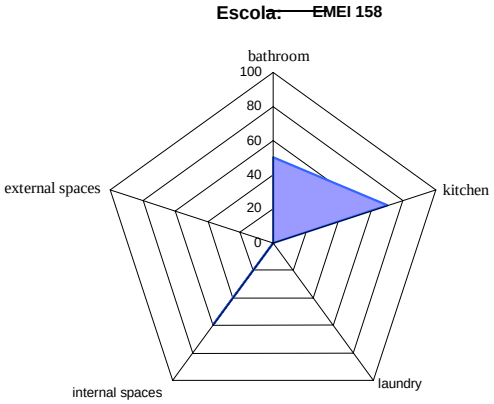

Figure 1: IU of EMEI 158 unit.

Figure 1 shows that the IU is higher for the activities performed in the bathroom and in the kitchen. For the school as a whole, this rate is lesser than 50%. It represents that it is necessary to develop an awareness program involving the activities performed in these rooms.

Considering all activities performed in all studied schools, it was verified that:

– the more frequent IU rate is 63%, but it occurs only in four of the 69 investigated schools. The average IU was 54%, which can be considered low,
– only one school the rate IU equals to zero and only one school had the maximum value of this rate (100%).

The more frequent values of IU for the activities performed in different school areas were:

– bathrooms: 50% (in 29% of the 69 units);
– outside areas: 0% (in 91% of the 66 units);
– inside areas: 100% (in 68.5 of 54 units);
– laundries: 100% (in 43.5% of 62 units) and
– kitchens:70% (in 20.3% of 69 units).

2.4 Water consumption monitoring

A remote metering system was installed in a sample of the surveyed schools, as follows:

- 02 CEMEI (nursery),
- 03 EMEI (kindergarten),
- 01 EMEI/FUMEC (kindergarten with adults' education in the evening period),
- 01 CEMEI/EMEI (nursery and kindergarten) and
- 01 CEMEI/EMEI/FUMEC (nursery and kindergarten with adults' education in the evening period).

The water monitoring was implemented for collect more accurate data, which were after used to formulate a model for water consumption in this type of building.

The employed data collection system was composed by a central computer with a data acquisition software, remote units for signal caption, water meters with a pulse exit, modems and telephone lines for data transmission from schools to metering center. Collected data were transmitted automatically, each 30 minutes, for storage and analysis. The phone line used was a conventional line used by the school and was programmed to send data during the night period.

3. Water consumption estimation model

A multiple regression model was developed based on collected data. The regression parameters were selected using the minimum square principle. The model fitting was checked by the value of the determination coefficient and by the residual analysis. For more details, see DRAPER; SMITH (1980), GUNST; MASON (1980), ELIAN (1988) and BUSSAB (1986). All statistical procedures were made with the following computational programs: SAS System version 8, EXCEL version 2000 e MINITAB version 12.

In order to formulate the model, the independent variable initially considered was the daily water volume consumed in week days (CD).

Dependent variables were classified in six groups:

- Building description: permeable and non permeable areas, number of classes, number of bathrooms and existence of vegetable garden;
- Kitchen usage: meal preparation or not in the school;
- Occupation pattern of the building: school population in each period;
- Environmental condition: maximum daily temperature;
- Plumbing fixtures: number of each type of fixture;
- Operation condition of the plumbing fixtures: number of each type of fixture leaking.

A preliminary analysis indicated the following variables as significant: permeable area (AP), non-permeable area (AI), number of classrooms (Nsa), total number of bathrooms

(NBt), number of employers' bathrooms (NBf), number of valve operated WC (BS/VD), number of valve operated WC with leakage (BS/VD-vz) and maximum daily temperature (Temp).

For a best model fitting, a transformation of the independent variable, that is, square root of the daily water consumption in weekly days (√CD) was made. Afterwards, some combination of the selected dependent variables was checked and resulted as follows:

- AI * BS/VD (non permeable area times number of valve operated valves),
- AI * Temp (non permeable area times maximum daily temperature) and
- BS/VD * Temp (number of valve operated valves times maximum daily temperature).

Table 3 shows the adjusted regression model. The estimative of the model parameters (bi) adjusted by minimum square and respective standard errors are presented in Table 3 The statistic t (= $b_i / EP(b_i)$) values and the descriptive levels (p-values) are also shown.

For a confidence level α (for example, equals to 5%), the b parameter considered different from zero if $p<\alpha$ (and null in reverse case). The determination coefficient (R^2) is shown in the last row of this table.

Table 3: Adjusted regression model for water consumption estimation.

	Independent variable : √CD			
	Coeficient	Standard error	t	p
Intercept (constant)	27,062	5,668	4,77	0,000
Temp	0,1507	0,2006	0,75	0,453
AI	-0,030276	0,007401	-4,09	0,000
BS/VD	5,8375	0,7785	7,50	0,000
AI* BS/VD	-0,000533	0,000090	-5,90	0,000
AI * Temp	0,001960	0,000260	7,53	0,000
BS/VD * Temp	-0,13460	0,02784	-4,84	0,000
R^2	0,6718			

The regression model to estimate water consumption in nursery and kindergarten units was adequate and is presented below:

$$\sqrt{CD} = 27{,}062 + 0{,}1507 * Temp - 0{,}030276 * AI + 5{,}8375 * BS/VD - 0{,}000533 * (AI * BS/VD) + 0{,}00196 * (AI * Temp) - 0{,}1346 * (BS/VD * Temp)$$

where:
CD – daily water consumption (week days), in L/day;
Temp – maximum daily temperature, in ºC;
AI – non permeable area, including paths, walks, in m²;
BS/VD – number of valve operated WCs.

It must be remarked that the obtained model is valid only for the school population from which the sampled schools were extracted and with similar variable magnitudes.

Figure 2 shows the independent variable CD predicted by the model and metered in the field.

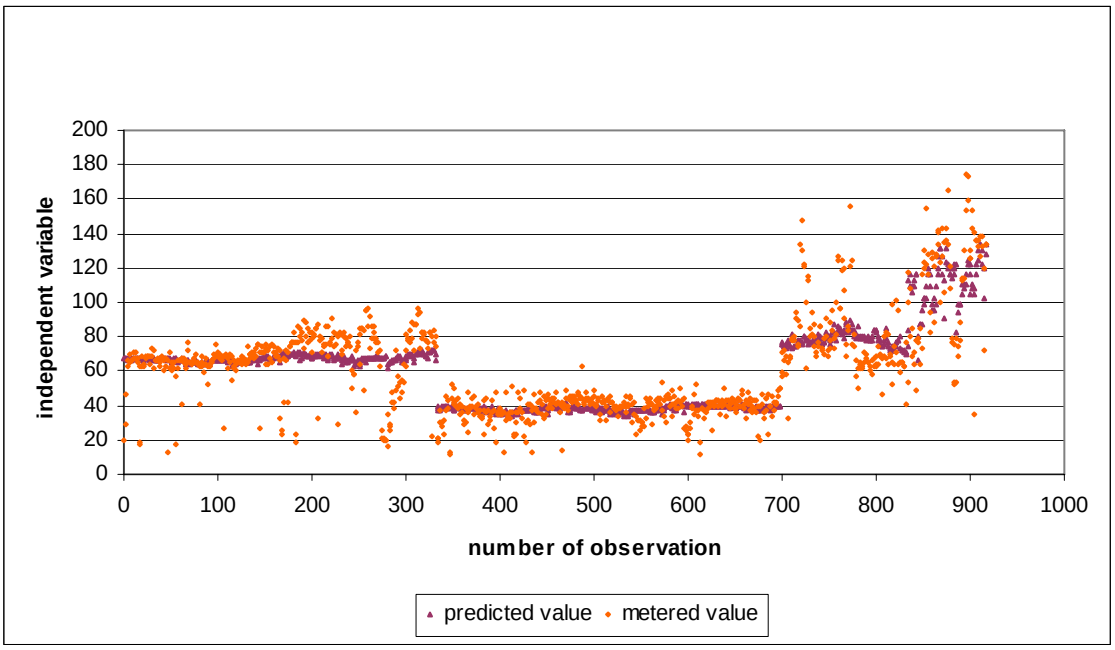

Figure 2: Predicted and metered values of CD.

4 Final comments

In order to develop consistent water conservation public policies, a deeper knowledge of the consumption indicator and water usage in different regions and in different typologies is needed.

This study showed the importance in considering the significant variables in order to determine the water consumption in buildings. The water consumption indicators traditionally used (L/person, L/bed, L/room, etc.) may lead to an inaccurate water consumption estimation, if other important variables like type of user, water usage, climate, etc. are not taken into account.

The model to estimate water consumption developed to the typologies here presented proved to be adequate for the studied population, as it can be seen in Figure 2 and the methodology developed in the study can be extended to other building typologies.

Acknowledgments

The authors thank the National Council for Scientific and Technological Development (CNPq) for support.

5 References

Bussab, W.O. *Análise de variância e de regressão*. São Paulo, Atual, 1986. 147 p.
CANO, W.; BRANDÃO, C. A. (coords.). *A região metropolitana de Campinas: urbanização, economia, finanças e meio ambiente*. Campinas, SP: Editora da UNICAMP, 2002.
Draper, N. R.; Smith, H. *Applied regression analysis.* 2. ed., New York, JOHN WILEY. 1980. 709p.
Elian, S. *Análise de regressão*. São Paulo, USP, 1988. 232p.
Gunst, R. F. ; Mason R.L. *Regression analysis and its application: data-oriented approach.* New York, Marcel Dekker, 1980.
Instituto Brasileiro de Geografia e Estatística (IBGE). Brasília, DF. Disponível em: http://www.ibge.gov.br/ . Acesso em 20 jul 2005.
Ywashima, L. A. *Avaliação do uso de água em edifícios escolares públicos e análise de viabilidade econômica da instalação de tecnologias economizadoras nos pontos de consumo.* 2005. 163p. Dissertação (mestrado) – Faculdade de Engenharia Civil, Arquitetura e Urbanismo da Universidade Estadual de Campinas (FEC/UNICAMP). Campinas, São Paulo.

6 Presentation of Main Authors

Marina Sangoi de Oliveira Ilha is Associate Professor at State University of Campinas, Brazil, Faculty of Civil Engineering, Department of Architecture and Civil Construction. She has Post-doctorate Degree in Civil Engineering. She teaches and conducts research in plumbing and fire protection systems.

Orestes Marracini Gonçalves is Professor at University of São Paulo, Brazil, Civil Construction Engeneering Department.