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Procedia Engineering 21 (2011) 929 – 938

Procedia Engineering

www.elsevier.com/locate/procedia

2011 International Conference on Green Buildings and Sustainable Cities

Water consumptions in public schools

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Abstract

Water consumption per user in non-residential buildings is still a very complicated issue for engineers and designers in the process of analyzing water demand and water management. It is easier to design for residential units than for public buildings, as you never know exactly how many users will access the building daily, you can just estimate the number. Our goal is not to set certain and fixed numbers, as they probably will never exist, but to analyze the data we gathered through time and to try to get to an approximation of water usage in public schools connected to building occupants. This research integrates quantitative data of water consumption through water metering and historical data about users in buildings. Six hundred buildings have been monitored over a period of 5 years (2005 e 2010).We focused on consumptions for 3 types of schools: Nurseries (0-3 years old children), Kindergartens (3-6 years) and Elementary Schools (6-11 years). Finally we studied how they are linked to building occupants on a daily consumption rate. The results are that the rational basic demand for water is estimated as 48 liters per pre-school student per day and 18 liters per elementary school student per day. Moreover younger children use more water on a daily basis than elementary school students, as they need more services, such as laundries and kitchens, whereas older students consume water mainly in restrooms.

Selection and/or peer-review under responsibility of APAAS

Keywords: schools, water consumption, Bologna Municipality, daily consumptions per occupant;

1. Introduction

School education is an important foundation of a nation, and deeply influences the development of society [3]. On the other hand, water conservation has become global issue and is important to society in

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1877-7058
doi:10.1016/j.proeng.2011.11.2096

recent years, and starting from what we know about the existing buildings is an important first step in all conservation programs. Linking water consumptions and school occupants is the goal of this paper, trying to set the basis for further conservation and educational interventions on this topic [3].

In fact, it is easier to design for residential units than for public buildings, as you never know exactly how many users will access the building daily, you can just estimate the number.

Our goal is not to set certain and fixed numbers, as they probably will never exist, but to analyze the data we gathered through time and to try to get to an approximation of water usage in public school buildings connected to building users.

Water consumption in buildings is usually estimated using a consumption indicator expressed by volume of water divided by consumers [2]. As in previous studies in the case of school buildings, we considered water consumed in m^3 and the building users as students, teachers and other stuff in school [3].

The results of this analysis can be helpful for engineers and water managers to have a reference in the process of dimensioning a water system and of designing infrastructures in public school projects.

Moreover the awareness of how much the existing buildings are consuming is an important starting point to set the future goals of how much we want to improve their performance in time [4], and how better the new constructions or the remodeled ones should be.

This research integrates quantitative data of water consumption through water metering and historical data about users in buildings.

However, water consumption load does not capture the individual conditions breakdown of a school and thus cannot guide water savings without further analysis, we set a non-dimensional water consumption index as a calculated parameter to establish a system of evaluation of consumptions, month by month. The design basis for the research and analysis of data is the water saving project of the City of Bologna: ACQUABO. Through the ACQUABO project 600 building, all located in the city of Bologna, in Emilia-Romagna region, Italy, have been monitored over a period of 5 years (2005-2010) to set a trend of consumptions and to be a starting point for future infrastructural and technical improvements. In between the various categories of buildings, our research focused then on public school buildings, as places where it is effective to promote water saving initiatives as they involve education and awareness and at the same time are easier than open-air spaces and other type of buildings to be analyzed for user consumptions. We wanted to set a performance indicator trend for pre-school and elementary school buildings.

Finally the data collected on recent consumptions (year 2009) have been used estimate water consumptions using variation index and the results have been linked to the building occupants.

Case study and Methodology

Study area: The ACQUABO project

The Green University of Bologna/Antartide Center, on behalf of the Municipality of Bologna within the "ACQUABO" project, has done an analysis of data of water consumption of users of municipal jurisdiction.

With ACQUABO the Municipality of Bologna, in collaboration with the University Verde di Bologna/Centro Antartide has set the goal to monitor and reduce water consumption starting from the public places like municipal buildings, schools, sport facilities, social aggregation areas etc. to be an example.

Historic consumption provided by Hera S.p.A. consisted of approximately 1-5 years of data and included both indoor and outdoor water use.

Six hundred buildings, owned by Municipality of Bologna, have been monitored over a period of 5 years (2005 e 2009) and then analyzed in order to get a trend of consumptions, to highlight anomalies and to have data to make intervention plans (against wastes, losses,.).

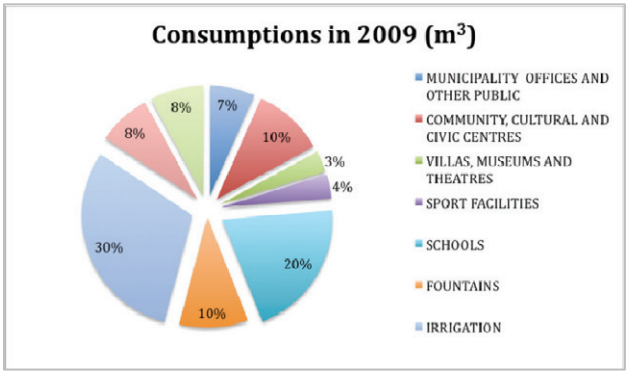

Fig. 1. Water consumption breakdown in Bologna Municipality

We used the data collected during the previous monitoring phase to study any developments in 2009 in comparison to the previous years (2005-2008); the goal was to identify sites with reliable consumption data and costs as well as possible anomalies and finally to select those trends that were found regular and discard the ones that had irregularities. The discarded ones presented data with low reliability as we found negative consumption numbers or values that were very different from the previous years.

The reference period identified for the analysis of data runs from 2005 to 2009 (Fig. 2). The evaluation over several years can minimize the influence of exceptional events such as special works and consumptions as well as any temporary losses. Data provided by the competent water authority of the City of Bologna refer to the consumption in cubic meters (Tab. 1).

Table 1. Total year water metering results

Cathegory	Consumptions in 2009 (m^3)	Case studies
MUNICIPALITY OFFICES AND OTHER PUBLIC	84,322.00	54
COMMUNITY, CULTURAL AND CIVIC CENTRES	133,649.00	32
VILLAS, MUSEUMS AND THEATRES	40,075.00	10
SPORT FACILITIES	45,241.00	13
SCHOOLS	259,463.00	134
FOUNTAINS	128,775.00	133
IRRIGATION	387,241.00	47
PUBLIC RESTROOMS	99,481.00	7
HYDRANTS	100,265.00	182

Utilities involved on the total five-year period have been aggregated in 9 major categories: Municipal offices and other Public Agencies; Community, Cultural and Civic Centers; Villas, Museums and Theatres; Sport facilities; Schools; Fountains; Irrigation.

In this group of case studies, after a first selection, it was decided to focus for further analysis on schools, as in 2009 Municipality of Bologna purchased 1.149.378 m^3 of water [1], and the major percent of consumptions was for schools and irrigation (Fig. 2). In order to be able to link consumption to building users, we focused on schools.

During the validation phase of the data, gathered through monthly technical readings of municipal metering devices, a variety of problems were found. What happened was that there were different gaps in readings and numerous instances of inconsistencies both between the different years and between the values in cubic meters and associated costs.

Because of that it was decided to develop the processing and analysis of data just on schools that had a certain continuity in consumption, as we did not want exceptional consumption cases, but we wanted to establish a baseline of consumptions in this category of buildings.

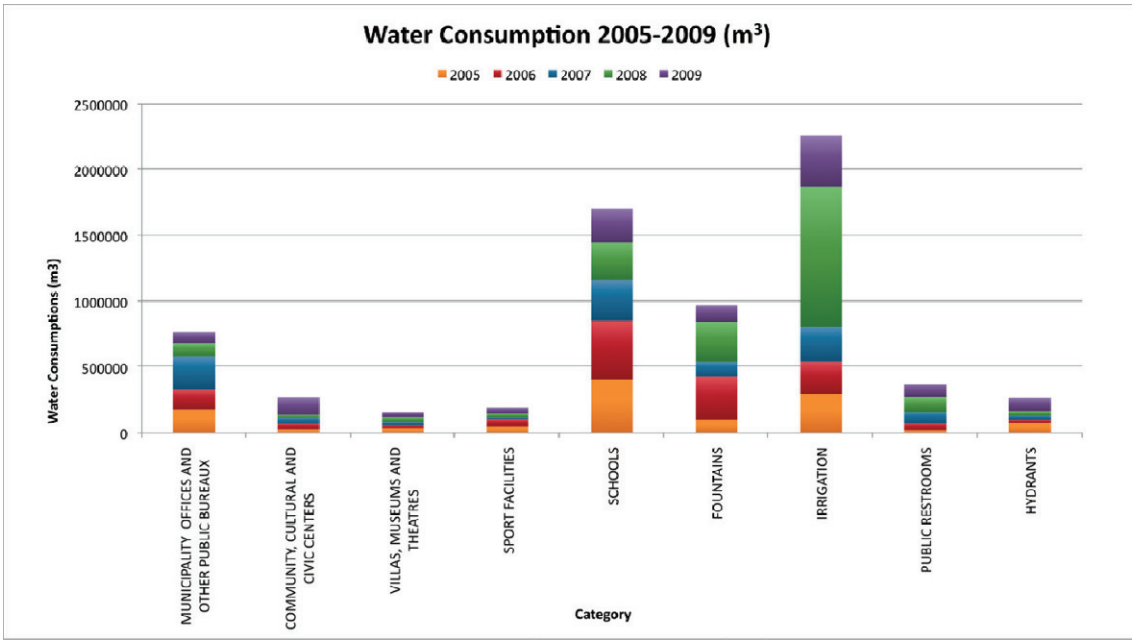

Fig. 2. Water consumptions in the 5-year study period analyzed for the 9 building types of study

Some remarkable inconsistencies between water consumption in cubic meters and associated annual trends have led to the decision of keeping only the ones with a linear acceptable course, but even in this case, however, it was decided to operate with some flexibility on a case by case basis.

Given the nature of the data and possible sources of error, we assumed that any meter showing negative peaks or suspect numbers indicated a misreading or a leak. These buildings were not included in our analyses as it would have skewed the results. For better problem resolution at these particular locations, further study may be warranted [4].

1.1. Data collection: Monitoring Bologna Municipality's consumptions in public schools

1.1.1. Intervention motivations

On the civil consumption level, community buildings are strategic locations for developing water analysis and conservation projects for two reasons:

- those places are the ones that have a *high consumption concentration*. A single targeted intervention can have proportional effects;
- these are the places where the concentration of people is higher: *high frequentation* places

1.1.2. Description and intervention breakdown

- STEP 1 – Data collection of water consumption and bill costs of public buildings: collection of information regarding the last annuities and following homogenization of data. The specific documentation provided by competent services of the Municipality was organized into categories by type of case study first, and then by type of school (Pre-school, Elementary school, etc.); everything was organized in years (2005 – 2009) (Tab. 2).

Table 2. School system in Italy for the studied school types.

Public Schools		Age (years)	Duration (years)	Time Schedule*
PRE-SCHOOL	NURSERY	0 - 3	2 years	7,30 am – 5,30 pm
	KINDERGARTEN	3 - 6	3 years	7,30 am – 6,30 pm
PRIMARY SCHOOL	ELEMENTARY SCHOOL	6 - 11	5 years	7,30am – 4,30 pm 7,30 am – 6,30 pm

**Frequent opening hours for schools in Bologna town*

- STEP 2 - The data were then processed through properly organized spreadsheets for multi-annual and seasonal time evaluations for school buildings. We did a data selection in order to filter the reliable ones and isolate those with anomalies in consumption, price, gaps, and discrepancies. The water monitoring was implemented to collect more accurate data, which were used later to formulate a trend for water consumptions in these type of buildings (Tab. 3).
- STEP 3 – The documents found in the Municipal Department of Education about building occupants of schools investigated were organized following the same categorization of water consumption data, to make it easier to link the two parts of the research.

Table 3. Example of an elementary school data analysis for water consumption in 2009.

YEAR 2009	MONTHLY CONSUMPTION (M)	AVERAGE MONTHLY CONSUMPTION IN A YEAR (Y)	M/Y
	m^3	m^3	INDEX
JANUARY	384.00	374.42	1.03
FEBRUARY	467.00	374.42	1.25
MARCH	404.00	374.42	1.08
APRIL	386.00	374.42	1.03
MAY	407.00	374.42	1.09
JUNE	359.00	374.42	0.96
JULY	447.00	374.42	1.19
AUGUST	130.00	374.42	0.35
SEPTEMBER	184.00	374.42	0.49
OCTOBER	509.00	374.42	1.36
NOVEMBER	439.00	374.42	1.17
DECEMBER	377.00	374.42	1.01
Total	**4,493.00**	**4,493.00**	**12.00**

- STEP 4 - Water metering and feedback on use patterns were then connected to students and building users in order to establish a per-capita user consumption.

The index used is the result of a simple equation: M/Y (Tab. 3) and indicates how the monthly value is related to the average monthly consumption that we had in the same year (1=average monthly consumption).

Findings from the charts indicate that of the existing fixtures inventoried, there is a period that runs from June to September (Tab. 3 and Fig. 3) where water consumption lows down. This validates data provided, as we expected to see this kind of course because of the holiday period in those months.

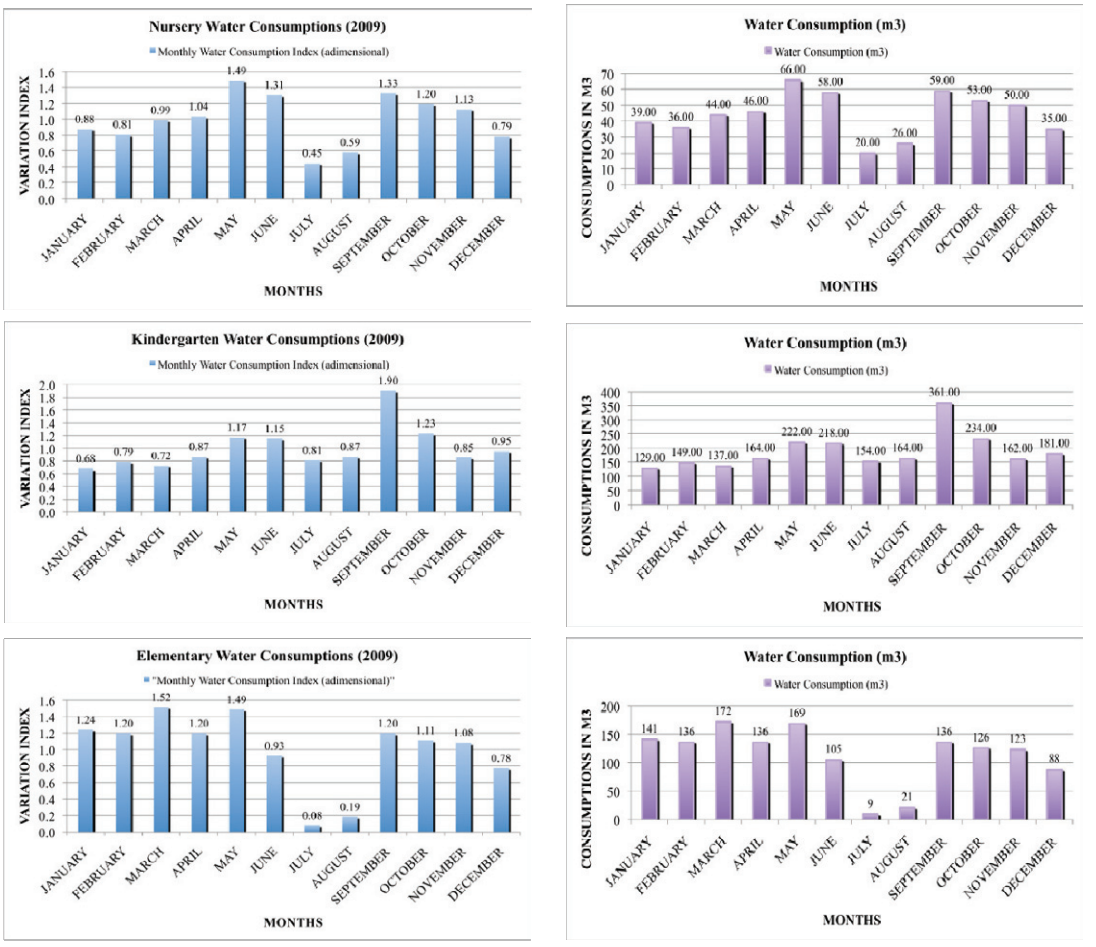

Fig. 3. Water consumptions for three benchmark schools, one for every type studied (Nursery, Kindergarten and Elementary School); the left side shows the water indicator analysis, and on the right there are consumptions in m^3.

1.1.3. Water use analysis

The collected data for various schools has been subdivided in Nurseries, Kindergartens and Elementary Schools (Tab. 2).

The historical data provided by HERA S.p.A. has been used to create an estimated water balance indicating water use per school (average estimation using data by month). Monthly data were selected from January 2009 to December 2009.

In the first part of the research project we wanted to organize the monthly consumption ranges for each case study to be sure that there were no inconsistent data. Moreover the results can be used as a start point to target the most wasteful facilities, and bring quantifiable savings to the Municipality of Bologna while promoting conservation and sustainability in the city and making intervention plans (against wastes, losses,..).

We notice that there is more continuity in pre-school facilities (Nurseries and Kindergarten) than in Elementary schools. This is due to a more various use of water in pre-school buildings, whereas elementary consumptions baseline is strictly linked to the user occupancy framework.

As in previous studies on this topic [2], we can guess that activities performed in different school areas of Nurseries and Kindergartens are bathrooms, laundries, kitchens, and sometimes irrigation. On the contrary, Elementary schools usually don't have kitchens or laundries so the water consumption is mainly due to toilet usage and sometimes irrigation.

By isolating Elementary school consumptions we can clearly perceive the range of data using a box plot graph, where we can see the extreme values and the average range of a 25%-75% percentile (Fig. 4).

Table 4. Focus on Elementary School case studies. The index refers to the relationship with the average monthly consumption

Elementary School n. / Month	1	2	3	4	5	6	7	8	9	10	11	12	Average Index
JANUARY	1.03	1.09	0.88	2.68	1.23	0.96	1.24	0.91	1.42	1.38	0.83	1.40	1.25
FEBRUARY	1.25	0.97	1.02	0.65	1.11	0.75	1.20	2.17	1.06	1.26	0.99	0.96	1.11
MARCH	1.08	1.04	0.70	1.12	1.17	0.67	1.52	0.95	1.23	1.02	0.91	1.67	1.09
APRIL	1.03	1.01	0.75	0.98	1.35	0.89	1.20	0.85	1.08	1.14	0.86	1.24	1.03
MAY	1.09	1.18	1.34	0.97	1.28	0.92	1.49	1.29	1.56	1.34	1.39	1.59	1.29
JUNE	0.96	0.29	0.73	0.31	0.27	0.25	0.93	0.71	0.48	0.43	1.00	0.24	0.55
JULY	1.19	0.89	0.67	0.28	0.97	0.09	0.08	0.12	0.16	0.51	1.30	0.05	0.53
AUGUST	0.35	0.73	1.11	0.45	0.21	0.55	0.19	0.91	0.25	0.08	0.45	0.00	0.44
SEPTEMBER	0.49	1.32	1.65	0.67	1.04	2.05	1.20	0.96	1.34	1.05	1.28	0.92	1.16
OCTOBER	1.36	1.08	1.11	0.85	1.14	0.96	1.11	1.48	1.58	1.70	1.05	1.90	1.28
NOVEMBER	1.17	0.99	1.27	1.86	1.13	1.04	1.08	1.03	1.10	1.23	0.85	1.28	1.17
DECEMBER	1.01	1.42	0.77	1.18	1.09	2.87	0.78	0.62	0.74	0.87	1.10	0.75	1.10
Average monthly consumption (year 2009) in m^3	374.42	289.67	196.42	200.33	133.67	191.42	113.50	112.83	109.83	106.75	112.50	98.75	170.00

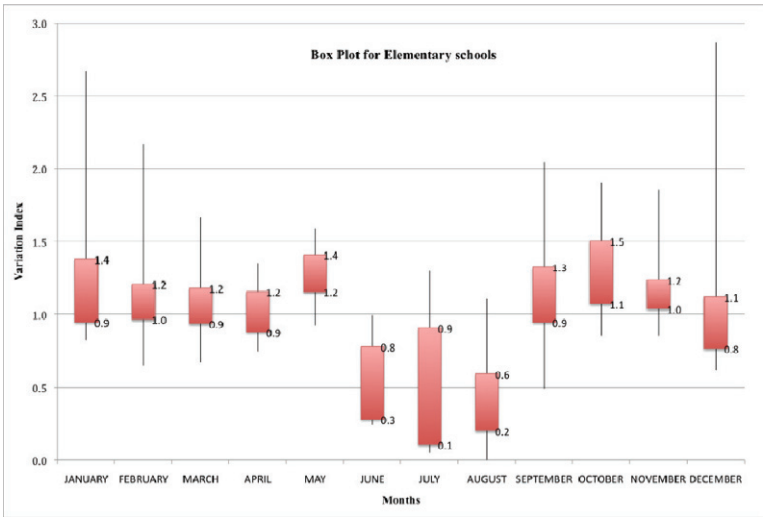

Fig.4 Box Plot for Elementary school water consumptions. Area extremes show the 25p and 75p (percentile); line extremes are maximum and minimum values

Table 5. Water Consumption in relation to building occupants.

	Type of school (N=nursery, K= kindergarten, E=elementary)	Annual mean consumption 2005-2009 (l/day)	Students	Water consumption (l/day*student)	Occupants (students, teachers, school stuff)	Water consumption (l/day*occupant)
1	N	7,327.7	133	55.1	166	44.1
2	N	3,529.9	67	52.7	88	40.1
3	N	2,764.4	38	72.7	50	55.3
4	N	3,656.4	55	66.5	73	50.1
5	N	3,716.2	55	67.6	73	50.9
6	N	2,809.3	55	51.1	70	40.1
7	N	1,817.8	26	69.9	37	49.1
8	N	1,489.9	27	55.2	36	41.4
9	N	3,591.8	75	47.9	88	40.8
10	N	1,460.3	39	37.4	50	29.2
11	N	1,340.3	27	49.6	36	37.2
12	K	6,730.8	113	59.6	145	44.1
13	K	3,449.3	125	27.6	144	40.1
14	K	6,767.8	137	49.4	170	55.3
15	K	2,726.0	75	36.3	86	50.1
16	K	2,259.2	75	30.1	86	50.9
17	E	9,238.9	347	26.6	382*	24.2
18	E	5,769.2	388	14.9	427*	13.5
19	E	5,221.4	440	11.9	484*	10.8
20	E	5,370.4	347	15.5	382*	14.1
21	E	2,697.0	250	10.8	275*	9.8
22	E	3,253.7	306	10.6	337*	9.7
23	E	3,754.0	185	20.3	204*	18.4

24	E	7,303.2	218	33.5	240*	30.5

**For elementary schools occupants an estimation has been done, as we just had the Student overall number: Teachers and Stuff were considered 10% of the Student value.*

Table 6. Average Water Consumption per student and per occupant for the three school types.

	Type of school (N=nursery, K= kindergarten, E=elementary)	AVERAGE Water consumption (l/day*student)	AVERAGE Water consumption (l/day*occupant)
PRE- SCHOOL	N	56.9	43.5
	K	40.6	33.6
PRIMARY SCHOOL	E	18.0	16.4

Our findings on school buildings are that the values of water consumption indicators show a 30 to 70 liters/student/day consumption in pre-school buildings and 10 to 30 liters/student/day in the case of elementary schools. Results also reveal that the basic demand for water by pre-school students is more than double than the one by elementary students, mainly because of the diversification of use of water in those buildings.

The analysis concerned the manner that students use water in the bathroom, kitchen, floor cleaning, watering garden and drinking in pre-schools, whereas in elementary schools it is usually just a bathroom and drinking value, sometimes embedding irrigation usage too.

2. Conclusion

The research was made on several schools to determinate a typical water consumption and to estimate a consumption distribution in the year. The water consumption distribution for various activities was seen in multiple results for the 3 major types of schools analyzed. Difference in school types mirrored the difference in uses and in student age. Laundries and kitchens are usually present only in schools that host children in pre-school programs, as they are younger and therefore need to be more looked after in everyday activities. As consequence they also have more school stuff, and their student daily usage differs from the occupant daily usage analysis breakdown for building consumptions. On the other hand elementary school students are more similar to office building users: they are at school during the opening hours, and they use water in restrooms and for civil uses mostly. They have holidays from June to September, and we can notice how consumptions low down in this period.

Using our results based on this investigation about water usage, we can set a performance indicator for consumptions in Nurseries, Kindergartens and Elementary schools. It can be a reference above which the situation can be considering alarming and to be monitored, as there is a suspect of leakage or anomalies.

According to previous researches and current investigations, the basic demand is determined from analyzing the characteristics of water consumption, as presented in Table 1. Meanwhile, the utilization frequency for water associated with individual schools is concluded, and the rational basic demand for water is estimated as 48 liters per pre-school student per day and 18 liters per elementary school student per day.

In fact average daily water consumption for a student enrolled in pre-school is higher than water used by a student in elementary school: older children consumption lows down to more than half of the younger ones consumption. We guess it is due to laundry and dining halls, as they are services needed to support education at this level.

Despite the fact that a determination of water consumption should account for individual situation of a school (kitchen, laundry, garden,..), we noticed that water consumption in the categories schools has some

common elements. Thus, we can use an average equivalent load per student as the basis for comparison and for conservation plan implementations. As inefficient infrastructures consume valuable water resources, material provided by our paper can be used as benchmark to target the most wasteful facilities, and bring quantifiable savings to the Municipality of Bologna while promoting conservation and sustainability in the city.

References

[1] Farina Marco, Pollastri Marco. *http://www.comune.bologna.it/ambiente/servizi/6:3456/5660/ , http://www.centroantartide.it/index.php/italian/archivio-news-news-105/287-acquabo-il-centro-antartide-e-il-comune-di-bologna-per-un-grande-progetto-di-risparmio-idrico.*

[2] M. S. O. Ilha, O. M. Gonçalves, S. V. de Amorim, L. P.Pedroso. *Estimating water consumption in nursery and elementary public schools*, CIB W062 Symposium 2005.

[3] Cheng CL, Hong YT. Evaluating water utilization in primary schools. *Building and Environment 2004*; **39**: 837- 845.

[4] *Water Analysis for Denver and Jefferson County Public Schools*, final report, Denver Water, Brendle group.

[5] Issa MH, Attalla M, Rankin JH, Christian AJ. Detailed analysis of elecricity, water, and gas consumption quantitied and costs in Toronto's public schools. *Can. J. Civ. Eng* 2010:**37**. NRC Research Press.