COVID – LOCKDOWN EFFECTS ON RESIDENTIAL DAILY WATER DEMAND PATTERNS IN CAMPANIA REGION

GLI EFFETTI DEL COVID-LOCKDOWN SULL'ANDAMENTO DEI CONSUMI IDRICI RESIDENZIALI GIORNALIERI NELLA REGIONE CAMPANIA

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ABSTRACT ESTESO

Un sistema di distribuzione idrico è caratterizzato da dinamiche principalmente dovute alla quantità di acqua richiesta dagli utenti e a quando essa è richiesta. Tali fattori che caratterizzano l'andamento della richiesta idrica giornaliera sono variabili casuali strettamente dipendenti dalle abitudini degli utenti e di conseguenza dal loro numero, dalle condizioni climatiche, dal tempo e dalla temperatura, dai costi dell'acqua, ecc. Negli ultimi due anni una pandemia dovuta alla diffusione del virus COVID-19 ha interessato il mondo intero e al fine di contenere la diffusione del virus, ogni Governo ha indetto misure restrittive alla popolazione come ad esempio la chiusura di scuole, Università, uffici, oltre ad attività produttive e industrie, costringendo la popolazione a non uscire di casa se non per motivi urgenti o per acquisti di beni di prima necessità. A causa di ciò, le proprie abitudini quotidiane sono cambiate e il diverso stile di vita imposto dalle misure restrittive si può vedere riflesso anche nell'abitudine degli utenti nella richiesta idrica.

Al fine di contribuire alla stima della domanda idrica residenziale giornaliera, valutandone la variabilità principalmente in funzione del numero di utenti forniti e delle loro abitudini, si sono esaminati dati di richiesta idrica residenziale registrati con intervallo temporale di 15 minuti in diversi comuni della Regione Campania per un numero di utenti variabile tra 7000 e 75000. In particolare sono stati posti a confronto i dati registrati nel periodo di Marzo-Aprile 2020 (primo Lockdown in Italia) con i dati dei mesi di Gennaio-Febbraio 2020 e dello stesso periodo (Gennaio-Aprile) relativi al 2019 in cui ancora non si era diffuso il virus e non vi erano misure restrittive in atto. Tali dati sono stati poi ulteriormente confrontati con il periodo di Gennaio-Aprile 2021, in cui era stato imposto alla Nazione un secondo Lockdown, ma con misure in riferimento all'economia del Paese meno restrittive rispetto al precedente. Non essendo chiuse le attività produttive e industriali, la popolazione poteva muoversi con maggiore libertà dalle proprie abitazioni anche se era invitata a non uscire se non per necessità. La scelta di esaminare e porre a confronto le richieste idriche registrate negli stessi periodi (Gennaio-Aprile) per i diversi anni, induce anche a trascurare le variazioni climatiche e di temperatura che potrebbero influenzare la domanda di portata. Come atteso, prima della diffusione del Covid-19, le richieste idriche giornaliere della popolazione presentavano andamenti diversi tra i giorni feriali e festivi. Tale differenza non si rileva nel primo periodo di Lockdown dove, essendo costretti nelle case, le abitudini delle utenze erano assimilabili ad un giorno prettamente festivo. La massima richiesta idrica in particolare per i giorni feriali, risulta traslata di un paio d'ore in avanti per tutti i comuni esaminati anche se è più evidente al ridursi del numero di utenti per i quali nel fine settimana si evidenzia anche un aumento del volume idrico giornaliero. Il secondo Lockdown, invece, essendo meno restrittivo del precedente, non comporta variazioni nelle richieste idriche giornaliere nei giorni feriali né nell'orario del picco mattutino, evidenziando un progressivo ritorno alla "normalità" nelle abitudini degli utenti nell'utilizzo idrico, pertanto dipendente dal relativo stile di vita sociale ed economico. I cambiamenti nelle abitudini dell'utenza dovuti a qualche condizione esterna, come la situazione di emergenza dovuta al Covid-19, non inducono ad una variazione permanente se non permanenti sono le variazioni socio-economiche. Al fine di prevedere la domanda idrica, pertanto, sarebbe utile conoscere la struttura sociale del quartiere residenziale e il suo sviluppo, nonché il numero degli abitanti serviti.

ABSTRACT

The chain of actions occurring in a water distribution system (WDS) depends on the amount of water required by users and when it is required: i.e. the water demand pattern. The latter, strictly dependent

on the users' habits, is a random variable and can be also influenced by number of users, climate conditions, weather and temperature, water costs, etc.
This paper aims at contributing to the estimation of the residential water demand by underling its variability mainly as a function of the number of users supplied and their habits. In particular, in the last two years, a pandemic due to the spreading of the COVID-19 virus has interested the whole world and has led people to change their lifestyle. This resulted in a changed demand pattern. This emergency situation has occurred in the last two years and has been characterised in Italy by two different Lockdowns. By examining the WDS water demand data before and during the first and second lockdown it is possible to highlight the difference in residential users demand patterns, contributing to the characterization of this random variable of great importance for the WDS managing/designing. The study was focused on the daily demand variation and a deep analysis has been tackled for the peak water request, by means of real demand data collected in different cities in the Campania Region and for a number of users ranging between 7000-75000. The analysis undertaken highlighted the role that the habits and the number of people supplied had in the residential water demand and their connection with the economic and social activities.

1. Introduction

The Covid-19 virus spread all over the world in the first months of 2020, causing a pandemic condition. Due to the numerous cases of sick people in intensive care units, all Nations had to adopt measures for limiting the virus spreading. One of these was the necessity of limiting the population movement by forcing them to stay home. This lockdown caused different habits in the population, by changing their normal way to behave.

In Italy the first lockdown (March-April 2020) disposed by the National Government was very strict due to the first wave of contagious people. Government measures, indeed, forced people to stay home, schools and all the commercial activity – apart first aid and basic necessities - were closed, as well as industries and productive processes. Furthermore, sanitary recommendation concerned frequent hand washing, while everything coming from outside needed to be cleaned.

In summer, the strict measures were released, but unfortunately a second contagious wave arrived in autumn 2020 and Government laws forced people to stay home again by closing schools and encouraging smart working but, this time, in a less strict way, being the commercial activities opened.

In the Campania region Government regulations were even stronger than the rest of Italy, however the second lockdown was less strict than the previous one and people had more freedom to leave their homes. This situation modified significantly people lifestyle, their economic and social life, and consequently their residential use of water.

The effect of the virus spreading on the WDS water demand patterns has been investigated all over the world, especially in reference to the first lockdown. In Brazil (Kalbusch A. et al, 2020) a decrease in the commercial, industrial and public consumption categories and an increase in residential users, higher in apartment buildings than in houses were reported. In Italy, a study referred to the Puglia Region (Balacco G. et al, 2020) reported variations in the daily demand volumes and changes in the daily demand pattern, showing that during the lockdown the morning maximum peak shifted to 2-2.5h later. Abu-Bakar H. et al. (2021) by means of a data-driven approach, used the behaviour of on network demand during the COVID-19 pandemic lockdown in England for improving the accuracy of demand forecasting. By analysing an apartment complex of 918 households in the Seoul metropolitan area of Republic of Korea, Kim D. et al. (2021) developed a machine learning model with an artificial neural network to predict the hot water use caused by COVID-19 pandemic. As a consequence of the changes in people lifestyle, the patterns of weekdays and weekends are assimilated. For selected developments in Dubai, United Arab Emirates, Rizvi S. et al. (2021) observed as a consequence of the COVID-19 crisis, a rise in the water consumption during the month of Ramadan, noticing a higher peak demand for low income areas than those with high income. Ludtke D.U, et al (2021), by analysing hourly and daily water consumption volumes of a utility in northern Germany, confirmed a shifted peak demand in the morning hours and an increase of the residential water consumption with higher morning and evening demand peaks during the day due to a net negative commuters accounting balance. Furthermore, they pose a warning for water utilities management if water use people behavioural changes will persist beyond the COVID-19 period, leading to the increase in water demand which may be a long term phenomenon.

By moving from this consideration, the aim of this work is to contribute to the estimation of the

residential water demand by underling its variability mainly as a function of the number of users supplied and their habits, analysing data collected before and during the first and the second Lockdowns.

2. Case studies and results

The study of how the change in users' habits can affect the residential water demand pattern was carried out by analysing water demand data collected by a remote-control system from Acqua Campania SpA Water Utility in some cities in the provinces of Napoli and Caserta. The different communities included 7000- 75000 users - *Inh* (Table 1) and were all characterized by indoor water use. Years 2019, 2020 and 2021 (the latter till June) were analysed with data collected with a temporal aggregation of 15 minutes. In order to avoid weather and temperature variation influence and thus comparing the analysed data, attention was focused on the period January 1st - April 30th for each of the three years considered. For the same period of the year indoor residential water demands in normal and in emergency periods were thus compared, during the first and the second Covid-19 waves.

In particular, the March-April 2020 period (Lockdown) and the previous January-February 2020 period were compared with the same period (January- April) of the previous year 2019 (normal consumption). Furthermore the 2nd Lockdown (January- April 2021) was analysed and compared.

For each year, weekdays were distinguished from weekends and holidays. Data collected by telemetric systems were previously analysed to exclude leakages and subsequently, in order to compare the patterns in the different periods, flow demand for every year and every 15 minutes of the day $Q(t)$ was considered adimensionally by means of the demand coefficient C_D in which μ_q is the daily mean flow in the considered period:

$$C_D = \frac{Q(t)}{\mu_q} \tag{1}$$

The mean C_D (μ_{C_D}) value for each ΔT of 15 minutes considered was plotted for each city analysed and for each period studied. As it was expected for small/medium residential areas (Gargano et al., 2016), the daily demand pattern was characterised by a low water demand during the night hours, and three daily peaks, one at the early morning (7.45 a.m.), one in the evening at dinner time and a less pronounced one at lunch time.

Analysing the pattern recorded in the period January-April 2019, before the Covid-19 spreading, it is possible to note a different behaviour between weekdays and weekends as it was expected. In the weekends the maximum water requested was shifted to two hours later with respect to a weekday (from 7.45 a.m. to 9.45 a.m.). This effect is evident in all the cases studied and it is more evident by reducing the number of users. It is possible to detect this same behaviour also at the beginning of the 2020 year, in January and February, in which the Weekdays 2020 Pre-Lockdown demand pattern was similar to the Weekdays 2019 pattern, being the users not influenced by a different lifestyle yet.

The pattern during the lockdown 2020 weekdays is quite interesting: the users, forced by the strict Government regulation to stay at home, not going to schools or work, behaved differently with respect to the daily use of water. In particular, as it is evident from the plots in Figure 1, in which some of the considered cities are reported, the daily demand pattern is still presenting minimum flow at night time and daily peaks, as it was expected, but, while the dinner peak is almost coincident, the early morning peak is shifted to 2h later. As a consequence, the 2020 Weekdays demand pattern during the Lockdown is comparable with the Weekends 2019 pattern (Figure 1). It is worth noting, however, that the night flow demand data are, for the different case studies examined, almost coincident *pre* and *during* the lockdown. Not going to schools or works, getting up later or not having the necessity to use water early for going out, users' behaviour in weekdays was the same as in weekends.

Furthermore, for the whole cases studied, as it is shown in Figure 2 for some of them, weekday and weekend patterns during the 2020 Lockdown were the same. This confirms that, having to stay home, any day of the week was considered by the population as the same. During 2020 Lockdown weekdays were equivalent to weekends in the use of water.

The 2nd Lockdown, however, being less strict with respect to the previous one, had demand daily patterns in line with the Pre-Lockdown period in terms of weekends (Figure 2) and weekdays (Figure 3). The second virus wave had a lower impact in changing the water requirement habits having the users a greater possibility to move and go out. Also, the productive and commercial activities were

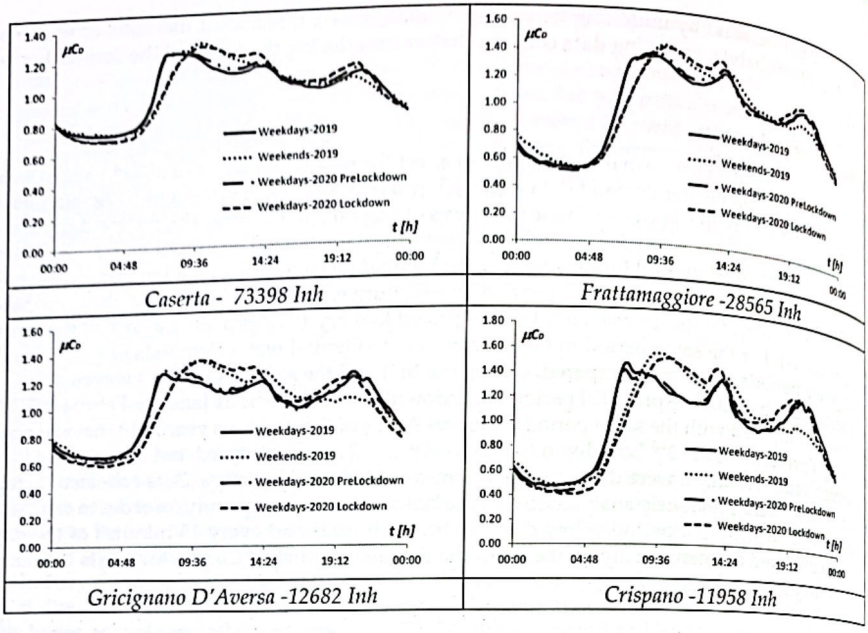

Figure 1 - Comparison between 2019 and 2020 weekday daily residential water demand patterns and 2019 weekends

Fig. 1 - *Confronto tra i patterns di domanda giornalieri per i giorni feriali per gli anni 2019 e 2020 e i giorni festivi del 2019*

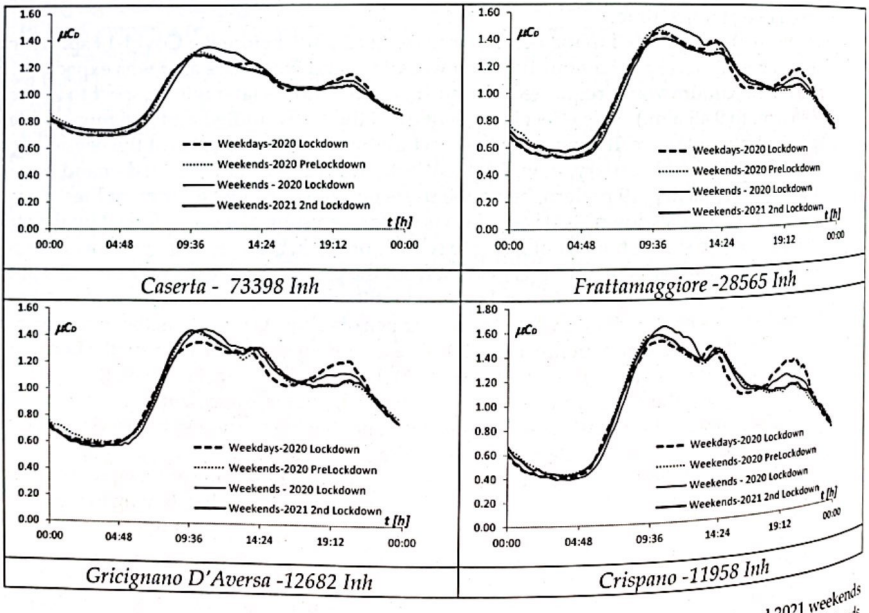

Figure 2 - Comparison between 2020 Lockdown weekday daily demand pattern and 2020 and 2021 weekends

Fig. 2 - *Confronto dell'andamento della domanda idrica giornaliera nei giorni feriali durante il lockdown con i weekends*

opened allowing a greater mobility. This result is of great interest because highlights that habits in the use of water is dependent on the social and economy lifestyle. Even if the pandemic situation was still an emergency and people still used a greater amount of water (handwashing, cleaning, etc), partial return to normality has led to an almost normal use of water, thus showing that the Lockdown condition led to temporary and not permanent different behaviour in the use of water.

While the weekday demand pattern changed during the 2020 lockdown period, by shifting the peak water requirement, the comparison between the mean daily volume recorded in 2020 PRE-Lockdown and Lockdown periods (Table 1), shows that globally the amount of water required by users is almost constant, presenting slight variations as a function of the number of users supplied.

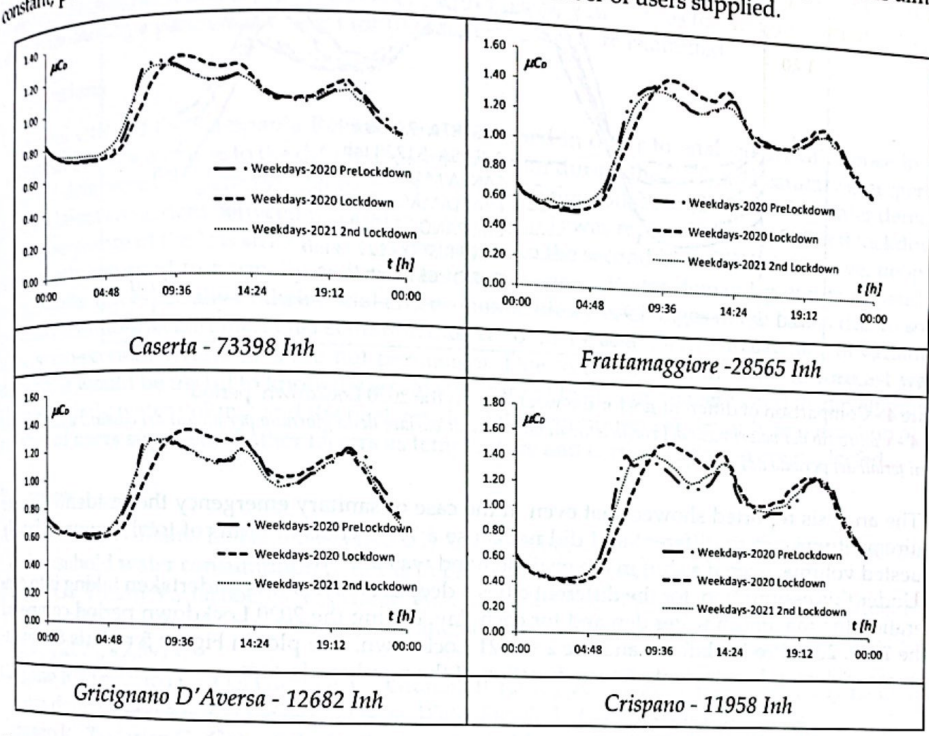

Figure 3 - Weekdays water demand patterns comparison between Pre-Lockdown and Lockdowns periods
Fig. 3 - *Confronto tra i patterns di richiesta idrica feriale nei periodi prima e durante i lockdowns*

		Mean Daily Volume [m³]	
	Inh	*Pre-Lockdown 2020*	*Lockdown 2020*
Caserta	73398	18894	18064
Aversa	51228	11637	11611
Caivano	36781	8086	7448
Santa Maria Capua Vetere	32183	9482	8903
Frattamaggiore	28565	6590	6425
Sant'Arpino	14857	2969	2475
Gricignano D'aversa	12682	2516	2680
San Prisco	12133	2368	2347
Crispano	11958	2210	2358
Succivo	8671	1518	1555
Curti	6819	1009	1178

Table 1 - Number of users (*Inh*) and mean daily volumes estimation for the different case studies
Tab. 1 - *Numero di utenti e stima dei volumi idrici giornalieri per i diversi casi in studio esaminati*

The comparison of weekday μ_{CD} in the 2020 Lockdown period for some of the case studies examined is reported in Figure 4. The adimensional flow comparison shows the variation of the different demand patterns as a function of the number of users. As the number of users decreased, the minimum night flow data decreased as well, while the early morning peak increased.

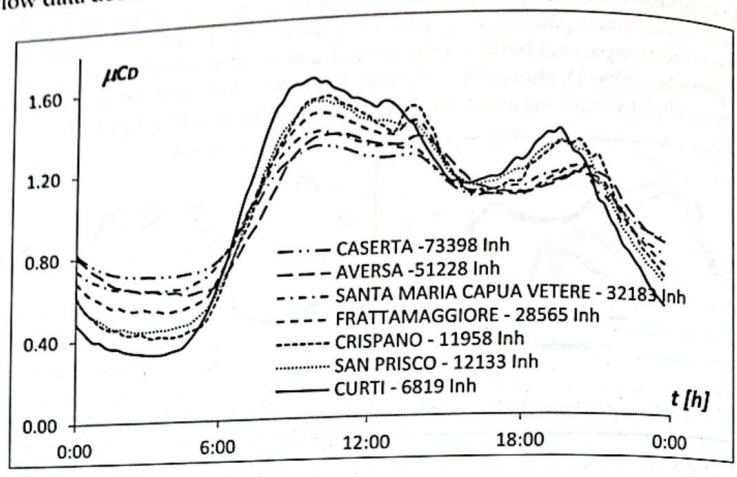

Figure 4 - Comparison of different μ_{CD} for the weekdays in the 2020 Lockdown period
Fig. 4 - *Confronto dei valori medi del coefficiente di domanda al variare della giornata per alcuni dei comuni analizzati nei giorni feriali del periodo di Lockdown 2020*

The analysis reported showed that even in the case of sanitary emergency the residential water requirement was not so different and did not cause a WDS crisis in terms of total amount of daily requested volume, even if a shift in the peak demand was present.

Under this assumption, for the different cities a deeper analysis was undertaken taking into consideration the maximum water demand for each day, during the 2020 Lockdown period compared to the 2019, 2020 Pre-Lockdown and the 2nd 2021 Lockdown. The plot in Figure 5 reports the maximum mean demand coefficient μ_{CP} as a function of the number of users.

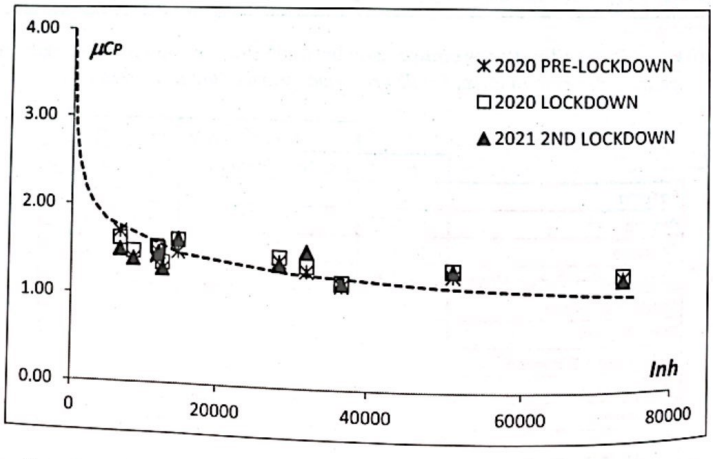

Figure 5 - Peak coefficient variation as a function of the number of users for the Pre-lockdown and lockdown periods
Fig. 5 - *Variazione del coefficiente di punta in funzione del numero degli abitanti nei periodi di Pre-Lockdown e di Lockdown*

The μ_{Cp} reduced when the number of users increased as it was expected. Furthermore, the retrieved data appear well fitted by the dot line in Figure 5 with respect to equation 2, which was obtained by Gargano et al., 2017 on a number of users ranging between 200-1250 *Inh*. This trend of the maximum mean demand coefficient, previously obtained for a smaller number of users, could be considered valid also for the case studies here examined which refer to a greater number of users ranging between 7000-75000 *Inh*.

$$\mu_{C_P} = 10\ Inh^{-0.2} \tag{2}$$

This result validates the relationship proposed by the Authors (Gargano et al, 2017) but at the same time highlights that it is possible to use the proposed relationships for designing/managing the WDS even during a pandemic, at least for the range of users here examined.

3. Conclusions

Several cities of the Campania Region were examined in order to analyze the difference in the residential use of water due to the different users' behavior during the 2020/2021 sanitary emergency. Collected data were compared with the same period of the previous year (2019), and a water demand pattern almost coincident between weekdays and weekends was reported during the first lockdown. As a consequence of the less strict lockdown measures, in the second 2021 COVID-19 wave, people's life partially returned to normally as it was before the crisis. Water demand patterns depend on users' habits, but especially of their social and economic lifestyle. Changes in the habits due to some external condition, as the emergency situation due to Covid-19, will not lead to permanent variations if the socio-economic variations are not permanent. Due to this aspect, in order to forecast water demand, it would be useful to know the social structure of the residential area and its development. The mean daily water volume and the peak residential consumption vary mainly as a function of the number of users supplied, if other factors as temperature and climate variation are neglected.

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