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Scientific Paper

Estimation of infiltration and inflow due to precipitation in a sewage basin

Estimativa da infiltração e afluxo devido à precipitação em uma bacia de esgotamento sanitário

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ABSTRACT

Extraneous flows to sewer networks can occur underground (infiltration) or in the routing of rainwater (inflow). Infiltration in these networks is often inevitable, leading to system overloads and causing overflows. The range of values suggested by the Brazilian standard for the infiltration coefficient is quite broad, which may result in the adoption of elevated or inaccurate values, leading to imprecise sizing and consequent expenses and problems that could be predicted or avoided. Sizing problems can lead to chronic operational issues. The application of methodologies for estimating infiltration and inflow due to precipitation (IDP) presents itself as an important tool in addressing these challenges. The objective of this work was to propose and test a methodology to estimate infiltration and IDP in a sewage basin in a coastal region (Florianópolis, Santa Catarina, Brazil). This methodology was developed based on the operational conditions available at the sanitation company. The aim was to use what was available, without costly acquisitions, and thus quantify these elements. For this, two distinct methodologies were applied: one for the quantification of the inflow and the other for the measurement of underground infiltration and determination of the infiltration coefficient. The results showed a directly proportional relationship between rainfall intensity and IDP value. The measured infiltration coefficients resulted in values higher than those adopted in the project. It is expected that this research will contribute to reducing network overload and improving local sanitation management.

Keywords: infiltration; inflow; sewer systems.

RESUMO

Contribuições indevidas nas redes de esgotos podem ocorrer no subsolo (infiltração) ou no encaminhamento de águas pluviais (afluxo). A infiltração nessas redes é um fato muitas vezes inevitável, gerando sobrecargas no sistema e ocasionando extravasamentos. A faixa de valores sugerida pela norma brasileira para o coeficiente de infiltração é bastante ampla, podendo resultar na adoção de valores elevados ou distantes dos que realmente ocorrem; levando ao dimensionamento impreciso e consequentes gastos e problemas que poderiam ser previstos ou evitados. Problemas de dimensionamento podem levar a problemas crônicos de operação. A aplicação de metodologias para a estimativa da infiltração e do afluxo devido à precipitação (ADP) se apresenta como uma ferramenta importante no enfrentamento desses desafios. O objetivo deste trabalho foi propor e testar uma metodologia para estimar a infiltração e o ADP em uma bacia de esgotamento sanitário em uma região costeira (Florianópolis, Santa Catarina). Essa metodologia foi desenvolvida a partir das condições de operação disponíveis na companhia de saneamento. Buscou-se usar o que estava disponível, sem aquisições onerosas, e assim quantificar esses elementos. Para isto, aplicaram-se duas metodologias distintas; uma para a quantificação do afluxo e outra para a medição da infiltração subterrânea e determinação do coeficiente de infiltração. Os resultados mostraram uma relação diretamente proporcional entre a intensidade de precipitação e o valor do ADP. Os coeficientes de infiltração medidos resultaram em valores acima do adotado em projeto. Espera-se, com a pesquisa, contribuir para a redução da sobrecarga na rede e melhoria da gestão do saneamento local.

Palavras-chave: infiltração; afluxo; sistemas de esgoto.

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INTRODUCTION

Extraneous flows to sewer systems can occur underground (infiltration) or through the routing of rainwater (inflow). Infiltration and inflow (I/I) have long been recognized as the main hydraulic problems in sewage systems. They can contribute to overloading the network and increased pumping costs, chance of overflows, dilution of effluent, and reduced efficiency of treatment facilities (ZHANG *et al.*, 2018; WANG *et al.*, 2019), as well as operational problems and, under extreme conditions, even accidents. For the efficiency of the sewage system adopted in Brazil, effective control is necessary to prevent rainwater from being routed along with wastewater. Otherwise, the absolute separator system works as a partial or combined separator without the transport and treatment structures being prepared for it.

Infiltration is usually of diffuse origin and can penetrate pipes through fissures, cracks, pipe joints, installation defects, material wear, etc. In turn, inflow mainly originates from singular inputs: poorly sealed manhole covers, irregular connections, and clandestine connections of pipes and storm water galleries, or abandoned connections (AZEVEDO NETTO, 1979; DIRCKX *et al.*, 2019; ZHAO *et al.*, 2020). Intrusion from rivers, extemporaneous tides, or sluices are other sources of direct inputs (METCALF; EDDY, 2016) that can cause overloads and are included in the inflow. In coastal regions, the effects of climate change and sea level rise are expected to place greater pressures on sewage systems.

The contribution of extraneous water is higher in places where rainfall is intense and the underground aquifer is high (PEREIRA; SOARES, 2006). In areas where the sewage collection system is below the water table, the infiltrated groundwater flow can range from 30 to 72% of the sewage flow (ZHAO *et al.*, 2020). I/I can be estimated and calculated by some traditional flow-based methods. In general, such approaches can be divided between qualitative and quantitative methods (KARPF; KREBS, 2011); where quantitative ones include hydraulic and chemical methods. Hydraulic methods generally make use of the balance of current discharge rates and theoretical wastewater plots to determine infiltration waters (KRETSCHMER; ERTL; KOCH, 2008), while chemical methods are those whose determination is based on the concentration of parameters related to wastewater, such as chemical oxygen demand (COD) for example.

Conventional methods for infiltration estimation are subject to considerable uncertainties due to their subjective assumptions and general principles that are not estimated. In addition, analysis of existing comparative studies reveals the challenges of applicability, such as ignorance of their existence, ignorance of the practices in other countries, and insufficient availability of long-term data series of flow rates and pollutant concentrations (DE BÉNÉDITTIS; BERTRAND-KRAJEWSKI, 2005). In many cities, problems in the sewerage network are related to aging infrastructure, lack of rehabilitation, execution issues, and the use of non-recommended materials (ZHAO *et al.*, 2020). As sewer network rehabilitation to reduce I/I is usually costly, water managers not only need methods to accurately measure I/I, but also require robust approaches to evaluate the actual performance of implemented rehabilitation measures (STAUFER *et al.*, 2012); a still incipient fact in developing regions. The challenges surrounding the assessment of infiltration and inflow in these regions may be structural (construction and pipe laying conditions), economic (acquisition of measurement equipment and materials), as well as social (enforcement and control of clandestine connections). The application of adapted methodologies using a combination of qualitative, chemical, and hydraulic methods to estimate the infiltration and inflow presents itself as an opportune tool to face these challenges.

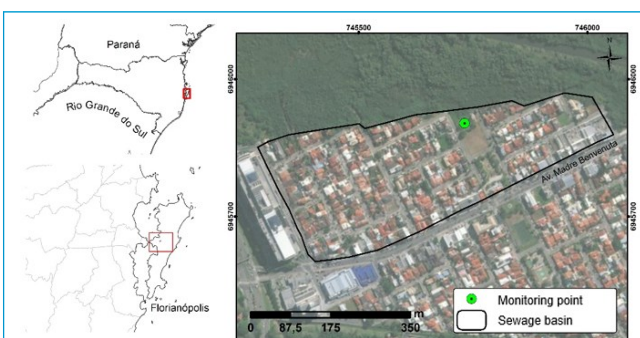
This work had two objectives. The first was to estimate infiltration and inflow in a sewage basin in the island of Florianópolis, Santa Catarina (SC), Brazil, a coastal region characterized by a history of intensive rainfall, tidal effects, and high water table. The second objective was, in function of the available data and equipment at the system operator's disposal, to select methodologies that could be implemented by the operator throughout the system and allow the evaluation of inflow and infiltration. The methodology proposed by Metcalf and Eddy (2016) was applied to quantify the inflow, in which the inflow is measured considering the difference between the volume accumulated on a significant rainy day and the volume accumulated during a dry period. To measure infiltration and determine the infiltration coefficient, the hydraulic methodology of minimum nightly flows was associated with the chemical methodology that uses the concentration of COD. The results directly contribute to understanding the problem and thus enable decision-making to reduce network overload, improve local sanitation management, and subsidize the choice of design coefficients.

METHODOLOGY

Study area

The island of Florianópolis is located on the coast of SC and has a humid subtropical climate, characterized by the maritimity, insular and continental relief nearby, and polar and tropical masses (MONTEIRO; FURTADO, 1995). Rainfall is well distributed among throughout the seasons, with a slight predominance of rainfall during the summer. According to the Geological Survey of Brazil (WILDNER *et al.*, 2023), the geomorphology is marked by features such as sandy barriers, lagoons, coastal lagoons, beach crest plains and wetlands associated with mangroves, as is the case with the basin under study.

The selected contributing basin was the tributary to the sewage pumping station (SPS) SB9-A (Figure 1), which covers the Santa Mônica neighborhood located in the central area of the insular part of Florianópolis. In addition, the Itacorubi mangrove to the north belongs to the local Itacorubi River Watershed with relatively shallow water table. It features low hydraulic gradients, porous, and permeable soils.



Source: the authors (2022).

Figure 1. Study area: Santa Monica Basin.

The region has predominantly urban activities (commercial and residential) and a large shopping mall that also contributes to the basin. According to data provided by the concessionaire that operates the basin's sewage network, there are 428 consumer units plus the shopping center.

The region is 100% served by water supply and sewage collection, with a population served of 2,041 inhabitants. This value is estimated from the household occupancy rate inferred from the 2010 Census by the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* — IBGE), the number of consumer units, and the equivalent population served by the mall. The basin covers 0.26 km^2 and receives contributions only from residences, without receiving contributions from other pumping stations. This fact reduces data losses due to overflows from upstream pumping stations. There is no measuring equipment to directly measure the variation of the flow in the sector. However, the company has a supervisory system that registers pump on/off and operation time. Therefore, the flow variation was calculated based on the pumping flow at the pumping station. To provide greater accuracy, the flow rate of the pumps at the lift was calibrated over a period of operation using a portable ultrasonic meter.

SPS is of the rectangular well type, equipped with a manual cleaning grid system and two submersible centrifugal pumps. The sewage is pumped to two other pumping stations and then pumped to the treatment station before being discharged for final disposal. The sewage collecting network consists of polyvinyl pipes (ochre, reinforced) with a diameter of 150 mm and total length of 3,301.49 m.

Determining the Pumping Flow

The flow data were obtained from the monitoring of SPS SB9-A and provided by the telemetry system of the concessionaire that operates the network, which records the operation (on and off the pumps) and the level of the pumping well per minute.

The calibration of the operation of the pumps was performed by direct measurement in the pump discharge pipe with an ultrasonic flow meter. After defining the average operating interval of the pumps, the calibrated meter was installed in the outlet pipe of the SPS. The pumps were turned off and the well was allowed to fill to the average upper level at which pumps usually shut off. Then, the pump was turned on, and the pumped flow per minute was measured to the average drive level. The same test was performed for each pump and for the association of the two pumps. The average pumping flows of each pump (P1 and P2) and both working together (P1 + P2) were used to determine the flows in the periods selected for the study.

Inflow due to Precipitation Quantification

For inflow due to precipitation (IDP) quantification, the methodology proposed by Metcalf and Eddy (2016) was used, where inflow is measured by considering the difference between the volume accumulated on a significant rainy day and the volume accumulated in a dry period (Equation 1).

$$\mathrm{IDP} = V_{Rainy} - V_{Dry} \quad (1)$$

Where:

IDP: inflow due to precipitation (m^3);

V_{Rainy}: daily sewage pumped volume on a significant rainy day (m^3);

V_{Dry} : daily sewage pumped volume on the corresponding day in the dry period (m^3).

A significant rainy day was considered a day with precipitation greater than 10 mm. Regarding the dry period, the adaptation made by Lamin and Sezerino (2012) was adopted for the present study, where the volume during the dry period corresponds to the arithmetic mean of the sewage volume pumped in the last three days prior to the significant rainfall event, with a minimum stay of seven days with precipitation of up to 4 mm.

Daily rainfall data for the study period were provided by the Epagri Information Center of Environmental Resources and Hydrometeorology of Santa Catarina (*Centro de Informações de Recursos Ambientais e de Hidrometeorologia de Santa Catarina* — CIRAM), which monitors a station with a rain gauge located 1 km from the study basin.

The sewage volume was estimated in m^3 per day by monitoring the operating hours of the pumps on the selected days multiplied by their respective average pumping flows.

Infiltration Quantification and determination of the Infiltration Coefficient

Infiltration was quantified by the methodology of minimum nighttime flows with estimated COD concentration proposed by Hanai and Campos (1997), adapted by Lamin and Sezerino (2012). The infiltration flow calculations start from the sewage concentration during the nighttime period (CODmean), which is the weighted average between the undiluted sewage concentration (CODswg) and the infiltration water concentration (CODinf) (Equation 2). The respective weights are the sewage flow (Fswg) and the infiltration flow (Finf) (Equation 3).

$$COD_{mean} = \frac{(F_{swg} * COD_{swg}) + (F_{inf} * COD_{inf})}{(F_{swg} + F_{inf})} \quad (2)$$

Where:

CODmean: mean COD concentration of sewage during the nighttime period of lowest affluent flow ($mgO_2.L^{-1}$);

CODswg: mean COD concentration of sewage during the period of greatest affluent flow ($mgO_2.L^{-1}$);

CODinf: COD concentration of infiltration water (will be considered null).

$$Fswg + Finf = Night\ Fmin \quad (3)$$

Where:

Fswg: pure sewage flow ($L.s^{-1}$);

Finf: infiltration flow ($L.s^{-1}$);

Night Fmin: lowest observed flow during the nighttime period ($L.s^{-1}$).

As CODinf is considered zero, the term in the equation that multiplies Finf is canceled out, leaving only Fswg as unknown. Once Fswg is determined, Equation 2 is employed once more to determine the infiltration flow (Finf).

Three dry weather campaigns were conducted to collect sewage and perform the COD test. Sewage samples were collected at the SPS entrance downstream of the grid, throughout the day, every hour. COD was analyzed at the Integrated Environmental Laboratory of Universidade Federal de Santa Catarina (LIMA/UFSC) using the closed reflux method. Together with the sample collection, salinity was measured, since the study basin suffers eventual tidal interference. If the salinity resulted in a value above 2 ppm, a value assumed based on the concessionaire's operational collection routine, the collection was suspended. This care should be taken because salinity interferes in determination of COD.

The infiltration coefficient was determined by dividing the estimated infiltration flow rate by the total length of the evaluated basin net (Equation 4).

$$i = \frac{Finf}{L} \quad (4)$$

Where:

i: infiltration coefficient ($L(s.km)^{-1}$);

Finf: infiltration flow ($L.s^{-1}$);

L: total sewer network length (km).

RESULTS AND DISCUSSION

Gauging of the pump flow rate

The average level range in the suction well of the pumps was 1.7 to 2.6 m. The measurements performed are shown in Table 1. The average flow rates obtained were 554.70 $L.min^{-1}$ for pump 1, 636.12 $L.min^{-1}$ for pump 2, and 806.64 $L.min^{-1}$ for the association of the two pumps. A standard deviation smaller than 0.5 was observed for the separate pumps indicating little variability of the flow rate during the measurements. The standard deviation was slightly higher in one of the tests with the pumps operating in association, reaching the order of 0.9, indicating greater variability of the pumped flow when the pumps operate in association. These standard deviation values allow, with a small margin of error, to infer the flow that actually circulates in the system, without the need

Table 1. Flow gauging for pumps 1, 2, and association.

	Test 1			Test 2			
	Time (h)	Level (m)	Fi ($L.s^{-1}$)	Time (h)	Level (m)	Fi ($L.s^{-1}$)	Fm ($L.min^{-1}$)
(P1) Pump 1	18:49	2.49	9.54	11:14	2.51	10.00	
	18:50	2.41	9.42	11:15	2.43	9.89	
	18:51	2.31	9.14	11:16	2.33	9.81	
	18:52	2.17	8.98	11:17	2.16	9.69	
	18:53	2.06	8.79	11:18	2.11	9.42	
	18:54	1.98	8.68	11:19	1.99	9.39	
	18:55	1.85	8.39	11:20	1.87	9.17	
	18:56	1.78	8.33	11:21	1.75	9.19	
	Mean		8.91			9.57	**554.70**
	Deviation		0.4			0.3	
(P2) Pump 2	19:10	2.56	10.94	11:32	2.52	11.45	
	19:11	2.44	10.94	11:33	2.48	11.48	
	19:12	2.32	10.57	11:34	2.37	11.11	
	19:13	2.21	10.48	11:35	2.22	10.84	
	19:14	2.08	10.35	11:36	2.11	10.72	
	19:15	1.95	10.13	11:37	1.96	10.49	
	19:16	1.87	9.90	11:38	1.81	10.35	
	19:17	1.74	9.80	11:39	1.73	10.00	
	Mean		10.392			10.81	**636.12**
	Deviation		0.4			0.5	
(P1+P2) Pumps 1 and 2	11:54	2.53	14.22	12:18	2.54	14.65	
	11:55	2.43	13.92	12:19	2.42	13.71	
	11:56	2.27	13.69	12:20	2.24	13.56	
	11:57	2.11	13.32	12:21	2.08	13.02	
	11:58	1.92	13.22	12:22	1.91	12.65	
	11:59	1.72	13.11	12:23	1.73	12.21	
	Mean		13.58			13.30	**806.64**
	Deviation		0.4			0.9	

Source: the authors (2022).
Level: level measured automatically in the pumping well and available in the supervisory system of the operating company; Fi: instantaneous flow measured with ultrasonic meter; Fm: pumping flow mean.

for direct measurement, using only what was already available in the operation of the system at the operating company. Thus, the methodology could be used in various sub-basins, presenting itself as an alternative for indicating infiltration values for the entire city.

Gauging was performed in order to obtain values closer to reality, since the option of using the theoretical flow rate of the pump is far from the actual flow rate due to factors such as time of use, wear of the pumps, and local conditions. The tests were carried out in dry weather conditions (P < 4 mm) and a portable meter available at the concessionaire was used for the flow determination tests. By multiplying the pump operating time (in minutes) by the mean pumping flows, it was possible to obtain the daily sewage volumes to determine IDP.

Inflow due to precipitation

The three events classified as valid for IDP determination are presented in Table 2. It shows the seven previous days without rain (Pdiary < 4 mm) and the daily precipitation of the day of the rain event. For each event, the average pumping flow rate defined in item 3.1 (Table 1) was multiplied by the running time of each pump, and the daily volumes of pumped sewage were obtained. In addition, from the difference between the rainy day's volume and the average volume of the dry period, the IDP values were obtained (Table 2).

The daily pumped volume during the selected events ranged from 229.1 to 781.1 m^3. The mean flow of dry period daily volume (MFDP) in all events was 290.2 $m^3.day^{-1}$.

The highest daily pumped volume occurred during event C, coinciding with the day of the highest rainfall and representing more than three times the average volume of dry weather, which indicates a considerable contribution of rainwater to the studied pumping station.

Another relevant result was the number of minutes the pumps remained on. It can be observed that the running time increases on days of heavy precipitation. Furthermore, almost all the days on which the pumps operated together were rainy days, except for April 12th, when an atypical discharge likely occurred in the network, causing the pumps to operate together for six minutes.

Figure 2 presents the resulting inflows, as well as the daily volumes of pumped sewage from the three events and the rainfall on the selected days. In Event A, the IDP represented 138.7% of the MFDP. Event B had the lowest rainfall in the rainy event (26.5 mm) and consequently the lowest IDP value.

Table 2. Characteristics of precipitation events A, B, and C, daily volumes and calculated inflow due to precipitation.

	Date (day of the week)	Pdiary (mm)	Time (P1) (min)	Time (P2) (min)	Time (P1+P2) (min)	Vtotal (m^3)	Vaverage dry time (m^3)	IDP (m^3)
EVENT A	04/2 (Sunday)	3						
	05/2 (Monday)	0.5						
	06/2 (Tuesday)	0						
	07/2 (Wednesday)	0						
	08/2 (Thursday)	0.8		716		455.35		
	09/2 (Friday)	0.8		624		396.93		
	10/2 (Saturday)	1.5	345	126		271.52	374.60	
	11/2 (Sunday)	42	354	0	720	777.14		402.54
EVENT B	06/4 (Friday)	0.3						
	07/4 (Saturday)	0.3						
	08/4 (Sunday)	0						
	09/4 (Monday)	0						
	10/4 (Tuesday)	0	484			268.47		
	11/4 (Wednesday)	0.3	413			229.09		
	12/4 (Thursday)	0	418	1	6	237.34	244.96	
	13/4 (Friday)	26.5	362	0	304	446.0		201.05
EVENT C	18/7 (Wednesday)	0						
	19/7 (Thursday)	0						
	20/7 (Friday)	0						
	21/7 (Saturday)	0						
	22/7 (Sunday)	0	433			240.18		
	23/7 (Monday)	0	441			244.62		
	24/7 (Tuesday)	1.6	484			268.47	251.09	
	25/7 (Wednesday)	71.8	191	0	837	781.10		530.01

Source: the authors (2022).
Pdiary: daily rainfall; Time (Pn): operating time of pump n; (P1): Pump 1; (P2): Pump 2; (P1 + P2): association of pumps 1 and 2; Vtotal: total volume of sewage pumped in the respective pumping time; Vaverage dry time: average volume of the 3 consecutive days preceding the day of the event; IDP: inflow due to precipitation.

Still, the total volume pumped (446 m³) during the rainy event represented an increase of 53.7% compared to the MFDP.

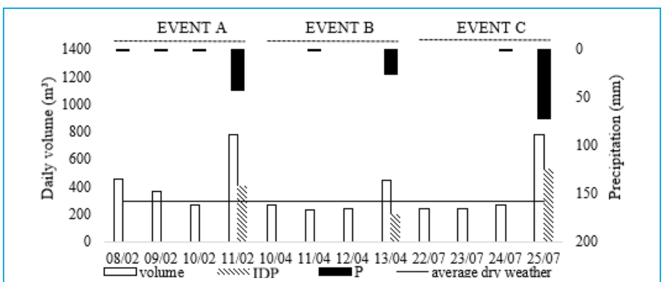
As expected, the highest IDP occurred in Event C, which had the highest rainfall on the rainy day (71.8 mm) and represented 182.6% of the MFDP. Tsutiya and Bueno (2004) concluded in their study that the contribution of rainwater to sewage systems is highly variable, reaching values from 26 to 283% of the MFDP.

It was observed that the daily volumes of the dry period of Event A differed from the volumes of the other events, presenting higher volumes. This was probably because Carnival 2018 took place from February 9th to 14th, and during this period the city received many people, leading to an increase in flow in areas with a concentration of restaurants, as is the case of the basin studied.

From the analysis and interpretation of the graphic, it can be inferred that the higher the precipitation, the higher the daily pumped volume and the higher the IDP. Furthermore, the IDP presented significant values, varying from 69.3 to 182.6% of the MFDP in the basin.

Infiltration

To quantify infiltration, three campaigns were also carried out. Similarly, the campaigns were performed after a period of at least 7 dry days and without tidal effects on the day of sampling. The days selected for hourly COD sampling were 04/24, 05/29, and 06/21. Other collection attempts were made on days that met the methodology, but there was rainfall or high salinity throughout the day. It is important to be aware of this limitation, especially when it comes to a region with high rainfall and islands. In addition, on these days, researchers must be available to remain on-site for many hours to collect samples, unless an



Source: the authors (2022).

Figure 2. Daily pumped volumes, inflow due to precipitation, and precipitation.

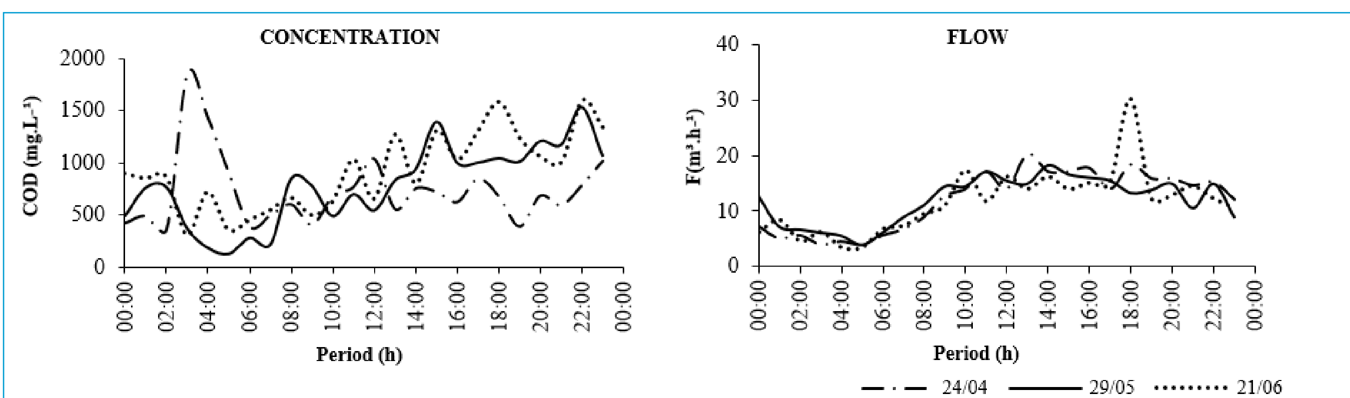
automatic sampler is available. The tributary sewage concentrations and hourly flows for the selected days are shown in Figure 3.

It is possible to observe the variability of sewage concentration throughout the day, with values ranging from 121.4 to 1854.7 mg.L^{-1} and average COD of 805.4mg.L^{-1}. A given concentration time on 24/04 showed a discrepancy with the data from the other campaigns, presenting a peak in the reading at 03h00. This peak coincided with a white liquid observed entering the well between 02h00 and 04h00. Based on the use and occupancy of the basin, it is believed that the liquid could be from washing discharge. It is evident that when working with real data from a dry weather pumping station, any unusual discharge can alter the quantity and quality of the affluent. The clandestine discharge of effluents into the sewage system is common. One should be aware of any change in the usual sewage concentration and the visual appearance of the sample.

It can be observed that the nighttime period with the lowest affluent flow occurred between 3 and 6 am; the sewage concentration during the nighttime period corresponded to the average concentration of sewage COD during this period (CODmean). The period with the highest affluent flow was between 11 am and 8 pm, where the concentration of pure sewage corresponded to the average concentration of COD during this period (CODswg). The minimum flow rate measured during the nighttime period (Fswg + Finf) was also obtained. Table 3 shows the experimental results obtained for each campaign.

Through the interpretation of the experimental results, it is possible to verify the significant interference of the unknown discharge in the resulting data from Campaign A. The fact that the time of arrival of the discharge at the pumping station coincided with the time of the adopted nighttime period raised the value of the CODmean, which was expected to be lower than the CODswg. Therefore, applying this value in Equation 2 resulted in a negative value for infiltration flow, which is not feasible.

For the two other campaigns, high values were observed for both fraction and infiltration coefficient, although within the recommended by the Brazilian standard. De Bénédittis and Bertrand-Krajewski (2005) state that methods based on nighttime flow and pollutant concentration tend to overestimate infiltration compared to other methods, due to the high uncertainty of instantaneous values. They also emphasize that these methods, when combined with chemical methods, are generally considered more accurate, though their application requires significant effort. It is worth highlighting that short-term infiltration



Source: the authors (2022).

Figure 3. Sewage concentration and flow.

Table 3. Experimental results for infiltration.

Campaign	A (24/4)	B (29/5)	C (21/6)	Unit
CODmean	1140.68	233.19	452.34	mg.L-1
CODswg	705.21	965.28	1121.69	mg.L-1
Fswg + Finf	3.89	3.89	3.33	L.s-1
Fswg	6.29	0.94	1.34	L.s-1
Finf		2.95	1.99	L.s-1
Infiltration		75.84	59.67	%
Infiltration coefficient		0.89	0.60	L(s.km)-1

Source: the authors (2022).

estimates may under- or overestimate actual effects of interannual seasonality, evapotranspiration, and groundwater levels.

The value of the infiltration coefficient of campaign C (0.60 L(s.km)$^{-1}$) was close to the value found by Festi (2006) (0.52 L(s.km)$^{-1}$) in his study in Borborema. However, both the coefficients of campaigns B and C were above what is adopted in the network projects by the concessionaire (0.4 L(s. km)$^{-1}$) in areas near the water table, as is the case with the studied basin.

CONCLUSIONS

This article presented proposed methods for IDP and infiltration quantification applicable to systems in coastal areas, with valorization of company operational data. The proposed methodology for estimating the average pumping flow rate proved adequate for monitoring locations without installed flow meters, which is the situation in most Brazilian pumping stations. The errors and uncertainties associated with the method proved irrelevant in face of the increase of information obtained through its application.

The IDP values found in the monitored system were 402.5; 201, and 530 m^3. There is a clear increase in pumping and well levels on rainy days. It is necessary to advance in identifying the source of this contribution and monitoring irregular connections to enhance the efficiency of the absolute separation system. The infiltration found ranged from 0.6 to 0.9 L(s.km)$^{-1}$, contrasting with the projected value (0.4 L(s.km)$^{-1}$). As seen in this case, the measured infiltration coefficient value may differ from the adopted one, since the design standard suggests a very wide range (0.05 to 1.0 L(s.km)$^{-1}$).

Sites with a recurrent history of heavy precipitation are more susceptible to the consequences of IDP. However, this characteristic hampers the prolonged dry periods necessary for the application of the methodology for determining infiltration. This factor should be observed when choosing the region, the measurement method, and the study period. In coastal regions, as is the case of the study region, tides tend to influence the sewage system. Therefore, it is crucial to monitor tidal variation, avoid collecting samples on days with high sea levels, and always measure the salinity of the sample to ensure the isolation of this interfering factor. Another alternative would be to adopt a procedure to remove salinity from the sample before performing the COD analysis. Salinity resulting from the entry of seawater can negatively affect the system, causing corrosion and changes in the properties of the effluent. Although the methodology used in this work does not include high-salinity samples, it is strongly recommended to evaluate seawater as extraneous flows and consider tidal effects on the system.

Investment in network rehabilitation programs is necessary, since the contributions in the form of infiltration and inflow directly influence the quality and quantity of the material used in sizing, as well as the useful lifespan and overload of the pumps and pumping equipment. Flow control on tip appears as an opportunity to assist in planning and developing contingency measures. With this case, we demonstrate that it is possible to quantify I/I in sewage systems using only operational data, effluent analysis, and a mobile flow meter that can be moved and used to calibrate the pumps throughout the operating system. Despite the relatively simple methodology, the gains from the information generated are very valuable to guide the operation and adoption of corrective measures to reduce operational costs.

AUTHORS' CONTRIBUTIONS

Finotti, A: Conceptualization, Project Administration, Funding Acquisition, Investigation, Data Analysis, Writing – Review and Editing; Broering, S: Methodology, Investigation, Data Analysis, Writing – Original Draft.

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