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Sampling Urban Stormwater: Lessons Learned from a Field Campaign in a Little Town of Spain

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Abstract

The water quality characteristics of urban stormwater in a small town (La Almunia, 8000 inhabitants) in Northeast Spain with a combined sewer system have been studied. A specific device was designed to collect stormwater just before it enters the drainage network at five different points in the urban area, thus obtaining an approximate calculation of the mean event concentration values for the surface runoff generated during eight rainfall episodes. The results obtained demonstrated a high variability in the average concentrations of the events. The highest measured values corresponded mainly to the periods of the greatest road traffic from agricultural machinery within the town (harvest and manure seasons), resulting in peaks mainly in electrical conductivity and dissolved oxygen demand. This finding has been confirmed by the spatial study of the results, since the maximum values of these parameters were located in those areas of preferential transit of agricultural machinery; in addition, a possible relationship has also been observed between the maximum values of nitrogen and phosphorus in stormwater and older urban areas, due to the washing of bird droppings accumulated on the roofs. In general, all obtained results indicate that the stormwater samples generated in La Almunia present a low contaminant load, with the mean concentration event values calculated for half of the events falling within the discharge limit values established by the European Union. This fact, combined with the spatial and temporal location of the highest levels of stormwater pollution, helps evaluate urban cleanup operations and the operational capacity of both the urban drainage network and the wastewater treatment plant.

Keywords: stormwater; pollution; urban catchment; combined sewer system; sewer inlet

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1. Introduction

Stormwater is water resulting from precipitation events, running off the urban landscape, collecting in storm sewers, and typically being released into receiving water bodies with little to no treatment [1]. This type of water carries pollution in both dissolved and suspended forms into the storm sewers of the drainage network. The collection, storage, and treatment of stormwater in urban areas have constituted one of the classical disciplines of environmental engineering in the past [2].

As stormwater flows over pavements, lawns, driveways, roads, and other urban surfaces, it accumulates high concentrations of contaminants from both point and non-point sources. Thus, relative to natural water or even sanitary-treated municipal wastewater, the quality of stormwater effluents is generally poor, and untreated effluents can result in acute or chronic toxicity in receiving water bodies, causing cumulative environmental problems [3]. Furthermore, the quality of urban stormwater exhibits significant variability in both time and space, and the continued release of chemicals from materials and human activities, coupled with advances in clean manufacturing and pollution control technologies, make source and contaminant identification a constantly evolving process, underscoring the need for continuous and adaptable sampling programs [4].

The nature of land use (i.e., industrial, commercial, residential) affects stormwater flow quantity and quality when considered in conjunction with climate, atmospheric, and catchment-dependent variables in urban [5,6] and non-urban areas [7]. Urban areas feature more contaminated and impervious surfaces, leading to rapid discharge peaks and high runoff volumes [8].

Another variable with decisive influence is the type of drainage system, which can be either combined or separative. In combined systems, stormwater is mixed with sewage and transported to wastewater treatment plants (WWTPs). In these cases, wastewater pollution has traditionally been considered to be diluted by "clean" stormwater. However, current understanding recognizes that these last waters are not pure and mobilize a considerable amount of pollution [9]. This mixing of waters causes significant changes in both the concentration of contaminants and the flow rate of the water being treated, which leads to frequent operational problems at the WWTP. In a combined sewer system, all waste water generated during dry periods is treated, but in heavy rain periods and when either the sewer system or WWTP capacities are exceeded, such overload is usually spilled out into the receiving water body, generating combined sewer overflows (CSOs) with significant physical, chemical, and microbiological degradation in the water quality of the receiving bodies [10–12].

For all these reasons, it is of particular interest to understand the concentrations of pollutants mobilized by urban runoff in combined drainage systems, in order to assist in both decision-making regarding the management of water flows treated in WWTPs and also the conditions of accidental spillage related to CSO.

This study analyzes the pollution of stormwater in La Almunia de Doña Godina (Zaragoza), a small town with approximately 8000 inhabitants whose drainage system is the combined type. The study was carried out on a small city because it can be modeled as a whole in a more accessible way than a larger city. Furthermore, cities with separative drainage systems do not pose pollution problems linked to stormwater management and flow peaks, as is the case with unitary drainage systems, resulting from the mixing of stormwater with wastewater that must be conveyed to WWTPs.

A stormwater sampling device has been specifically designed to collect samples of runoff reaching the water drain inlets before mixing with urban wastewater.

Eight sampling campaigns were carried out between August 2024 and April 2025, conditioned by the climatic characteristics of this area, with low total rainfall (mean around 420 mm/y) and a very irregular temporal distribution, typical of a temperate continental Mediterranean climate. All these collected samples, distributed across five different locations in the town's combined drainage system, were subjected to laboratory analysis, where the usual parameters for this type of study were determined. The geographical distribution of the sampling points can be seen in Figure S1, provided as Supplementary Material; this location was decided based on a previous study in which all the town's drainage inlets, their geometric characteristics, and their loss of efficiency due to clogging were inventoried [13]. Its distribution allowed for representative consideration of the entire drained urban area (around 1.2 km^2).

The sampling methodological approach combined with the results obtained allowed for the assessment of the polluting impact produced by stormwater runoff in a small Spanish town with a geographical characterization of pollutant source depending on land types. The purpose of this study is to characterize the pollution potential of stormwater before it enters the urban drainage system. The problems of managing overflows when they reach the wastewater treatment plant are well-known, and these are resolved by discharging them directly into the natural environment without treatment. Therefore, understanding the compositional characteristics of rainwater and its spatial and temporal variability is crucial to support decision-making regarding the direct discharge of this water before it enters the drainage network.

2. Materials and Methods

2.1. Sampling Methodology

It is well known that stormwater removes a significant proportion of pollutants from the street surface during the first occurrence of rainfall [14,15]. Therefore, there are methodologies that allow samples to be separately collected at predetermined time intervals (for example, every 10 min) throughout a rainfall event, thereby characterizing the evolution of the pollutant load concentration over time. In our case, due to both the type of rainfall and the combined nature of the drainage network, an automated device was designed that allowed for samples to be taken during the generation of surface runoff. Pumping was carried out when the water reached the sewer inlet, and always before entering the sewage system. This procedure has made it possible to determine the average chemical composition of the runoff generated in each rainfall event, thus including the first flush, which contains a higher degree of pollution; this value is more representative of the potential contamination since it takes into account the flow generated with its actual concentration [9]. The analysis of samples obtained in this way represents the event mean concentration (EMC), that is, the flow-weighted average concentration of pollutants in runoff during a specific storm event [16]. EMC is usually considered a key analytical parameter for assessing both the quality of stormwater and its impact on the receiving natural aquatic environment [17].

The designed device in this work (Figure 1) is housed inside an IP65 case (AUER Packaging, Amerang, Germany), and it includes a suction pump (Técnica de Fluidos S.L.U., Ciempozuelos, Spain), a programmable automaton (Logo!24RCE, Siemens, Munich, Germany), a miniature circuit breaker (MCB, PIA 6A, Siemens, Germany), a set of batteries of 12V and 7 Ah (Yuasa Battery Europe Ltd., Dusseldorf, Germany), and a 2-liter-capacity polyethylene flask to store the sample collected during the event. On the outside of the case, there is a rain gauge (Pronamic, Skjern, Denmark), which is the element that controls the start-up of the suction pump when a certain precipitation level (defined by the user) is reached. Each sample was collected using a hose with a non-return system, which prevents the circuit from running out of water and prevents it from flowing in only one direction (always toward the sample storage tank). The device has been registered as a utility model in the Spanish Patent and Trademark Office [18]. This is a legal protection for inventions that involve improvements on existing objects, in this case, water sampling devices.

In this work, a value of 5 mm was selected according to local experience, since it has been considered as the precipitation threshold for the development of sampleable surface runoff. For the campaigns carried out for this work, individual sample volumes between 0.3 and 1.2 l were collected, the total volume depending on both the distribution of precipitation for each event (total rainfall and intensity) and the type of sewer inlet, siphonic or non-siphonic. The sampling devices were properly cleaned in the laboratory before each recorded event, and rainwater samples were collected directly as rain fell into the sewer inlets.

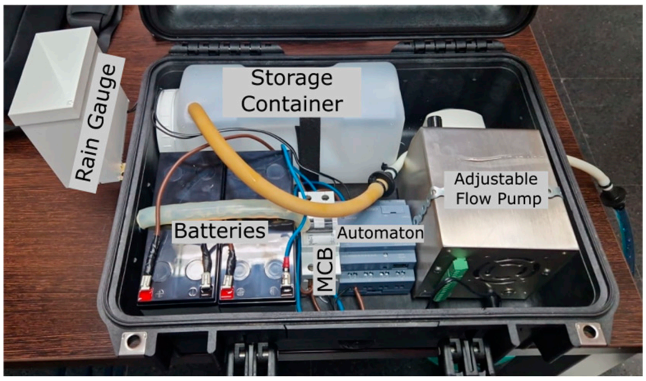

Figure 1. Stormwater sampling device designed and built in this work.

2.2. Analytical Routine

The stormwater samples collected were immediately stored at low temperature (around 4 °C) until performance analyses in the laboratory within 24 h. The sampling period spanned from August 2024 to April 2025, thus covering all meteorological seasons.

The analytical routine was designed according to both the typology of the samples (including the available collected volume) and the control parameters usually considered in this kind of research [9]. As physical-physicochemical parameters, pH, electrical conductivity (EC), turbidity, and chemical oxygen demand (COD) were measured on the collected samples. In addition, concentrations of nitrate, total nitrogen, total phosphorus, copper, zinc, and total chromium were analyzed. All these analyses were performed in the AG Erikson laboratory (Calatayud, Spain), following Standard Operation Procedures for water samples. Given the operating conditions of the device and the characteristics of rain events in this area (both total precipitation and duration), the analytical results obtained from the collected samples were considered representative of the event mean concentration (EMC).

3. Results

Eight sampling campaigns were carried out at five different locations in the town during several rainfall episodes with precipitation exceeding 5 mm between August 2024 and April 2025. A total of 35 stormwater samples were collected just as they entered the sewer inlet, before mixing with urban wastewater. Figure 2 shows the placement of the sampling devices ready for operation at four of the locations as an example.

The availability of five devices allowed for sampling the selected points simultaneously and automatically, although some acts of vandalism prevented the completion of several of the sampling series. Table 1 shows information about the sampled events (date, total daily precipitation, and previous days without significant precipitation), as well as the number of samples collected in each event, taking into account that not all series could be completed as a result of vandalism. This fact made us decide that the devices should be placed and removed for each rainfall event to be sampled, thus minimizing possible damage or even theft of the devices.

The total actual seasonal rainfall during the sampling period was 232 mm, distributed as follows: 41 mm in summer (mid-June to mid-September), 46 mm in autumn (mid-September to mid-December), 83 mm in winter (mid-December to mid-March), and 62 mm in spring (mid-March to mid-June).

Av/Madrid sampling point

Tenerías sampling point

Pza España sampling point

Av/Zaragoza sampling point

Figure 2. Sampling devices placed at four of the five locations selected for this work in the town of La Almunia.

Table 1. Information about rain events sampled in this work (source: State Meteorological Agency, open data, AEMET).

Date of Sampled Rain Event	Total Daily Precipitation (P_D), mm	Antecedent Dry Days ($P_D < 5$ mm)	Samples Collected
29 August 2024	6.8	38	5
10 September 2024	13.6	15	5
29 October 2024	11.8	19	5
10 November 2024	6.5	12	4
4 March 2025	9.6	16	5
17 March 2025	8.8	13	4
25 March 2025	7.6	8	4
7 April 2025	14.4	13	3

The deployment of the devices was then decided based on weather forecasts. Thus, when the forecast predicted a high probability of rain exceeding 5 mm, the devices were placed. However, there were rain events that prevented sample collection (because the actual rainfall was less than expected), and there were also events that were not sampled because the actual rainfall was much higher than expected. All of this implies that the sampled events indicated in Table 1 were only a part of those that occurred between August 2024 and April 2025, capable of generating an effective runoff. During this entire period, only fifteen rainfall events exceeded the daily precipitation level that generated runoff (5 mm), of which eight were sampled and, therefore, seven of them were missed.

Table 2 shows the analytical results obtained in the laboratory for all individual samples collected. The first column indicates the geographic location, and the samples appear grouped by each of the sampled events, according to the correlative order expressed in Table 1.

Table 2. Result obtained after chemical analysis of stormwater samples, which appear chronologically grouped by event.

Location	Date Event	pH	EC (µS/cm)	Turbidity (NTU)	COD (mg O_2/L)	N Tot (mg/L)	Nitrate (mg/L)	P Tot (mg/L)	Cu (µg/L)	Zn (µg/L)	Cr Tot (µg/L)
Plaza España	29 August 2024	7.7	370	3.0	43	31.0	6.6	0.75	25.0	45.0	11.0
Av/Madrid		7.9	1000	<0.7	47	7.9	22	<0.2	6.5	40	11
Tenerías		7.4	190	2.2	75	5.9	2.9	<2	8	101	11
Av/Zaragoza		7.7	280	8.6	46	4.9	2.6	0.21	117	183	11
Sta. Pantaria		8.0	1340	6.0	252	12.0	<2.2	<0.2	19	81.0	12
Plaza España	10 September 2024	7.7	120	3.0	114	6.4	6.0	0.93	60.0	345.0	16.0
Av/Madrid		8.1	180	1.6	53	1.2	<2.2	<2	17	111	13
Tenerías		8.3	430	6.8	142	15.0	6.8	<2	70	159	12
Av/Zaragoza		8.0	130	1.5	27	3.0	<2.2	<0.2	39	82	11
Sta. Pantaria		7.7	260	1.4	56	5.1	4.5	0.3	21	131.0	12
Plaza España	29 October 2024	8.0	800	>10	525	19.0	7.0	5.5	48.0	57.0	<1
Av/Madrid		7.9	380	>10	264	5.7	<2.2	1.8	9.8	44	<1
Tenerías		8.1	380	>10	84	4.6	<2.2	1.5	7.3	35	<1
Av/Zaragoza		8.2	300	3.8	56	2.2	<2.2	0.23	62	39	<1
Sta. Pantaria		7.8	160	1.9	56	3.6	9.7	0.3	8.6	65.0	1
Av/Madrid	10 November 2024	8.0	390	>10	150	4.7	<2.2	2.1	21	132	1.6
Tenerías		8.0	380	>10	84	5.5	<2.2	2.3	15	100	1.3
Av/Zaragoza		8.0	300	>10	159	4.7	<2.2	0.72	223	223	3.1
Sta. Pantaria		7.7	160	2.9	150	3.8	7.9	0.3	33	244.0	4.9
Plaza España	4 March 2025	7.7	200	>10	2340	6.7	1.1	1.5	34.0	<10	0.0
Av/Madrid		7.7	250	>10	365	6.5	1.7	0.99	56.0	<10	0.0
Tenerías		7.4	270	>10	3270	5.9	<0.5	2	92	<10	0.02
Av/Zaragoza		7.9	350	>10	600	2.4	<0.5	1.2	71	<10	0.018
Sta. Pantaria		7.9	290	>10	84	4.9	1.3	0.3	33	<10	0.011
Plaza España	17 March 2025	7.2	360	>10	345	22.0	2.3	<1	115.0	<10	8.3
Av/Madrid		7.4	270	7.8	50	<5	1.1	<1	38.0	<10	1.7
Tenerías		7.2	310	>10	75	<5	<0.5	<1	86	<10	1.8
Sta. Pantaria		7.5	240	6.4	37	<5	1.1	<1	12	<10	2.1
Plaza España	25 March 2025	7.3	240	>10	166	15.0	2.5	<1	107.0	<10	6.7
Av/Madrid		7.4	110	4.5	38	<5	<0.5	<1	30.0	<10	<1
Tenerías		7.5	330	3.9	47	<1	<0.5	0.25	40	<10	<1
Sta. Pantaria		7.1	150	3.9	32	<5	<0.5	<1	19	<10	2.1
Av/Madrid	7 April 2025	7.8	47	1.9	19	<5	<0.5	<1	16.0	<10	1.3
Tenerías		7.7	270	>10	221	<5	<0.5	<1	28	<10	13
Sta. Pantaria		7.5	520	>10	113	7.3	<0.5	<1	131	<10	2.8

For a better understanding of these results, an overall descriptive statistical treatment has been carried out using all the data obtained from sample analyses. Table 3 shows the main results obtained in this data processing, including typical values in urban runoff reported by US-EPA (1999) [19], and the legal European limits for discharge are also shown. The values recorded in [19] as typical in urban runoff collected in separating networks have been incorporated for comparison purposes, and therefore correspond to conditions similar to those of the samples analyzed in this work, since, although the La Almunia sewer network is combined, the samples were taken before mixing with domestic sewage wastewater.

In general, a certain variability is observed in the values obtained, as indicated by the standard deviation relative to the average values for all the analyzed parameters, especially in both electrical conductivity (EC) and COD. Despite this, the values here obtained are within the ranges determined as usual for urban runoff according to the US-EPA (1999) [19]. Variability is related to various factors, including the intensities of the rainfall events and the different time intervals between successive rain events, as has been frequently reported in the literature [5], and it will be discussed in the next section. It is important to keep in mind that stormwater concentration will depend on multiple factors that combine differently in each rain event. Thus, rainfall with a prolonged previous dry period is expected to result in high dissolved concentrations, but intense rainfall will result in highly diluted samples. If spatial variability (drained area, pollution points) is added, it becomes extremely difficult to obtain precise general correlations between these variables, beyond specific relationships.

Table 3. Statistical summary of analytical results, with indication of average value, standard deviation, and maximum and minimum values. Typical values in urban runoff (US-EPA) and the legal European limits for discharge (EC) are also shown.

Parameter	Units	Average Value	Max. Value	Min. Value	Standard Deviation	US-EPA (1999)	Discharge Limit (EC)
pH	pH units	7.72	8.3	7.1	0.30		
EC	µS/cm	336	1340	47	253		
Turbidity	NTU	3.95	8.6	1.4	2.37		
COD	mg O_2/L	291	3270	19	652	200–275	125
Nitrate	mg/L	5.12	22	1.1	5.15		
Total N	mg/L	8.03	31	1.2	6.85	0.4–20	15
Total P	mg/L	1.38	7.5	0.21	1.68	0.02–4.3	2
Cu	µg/L	49.1	223	6.5	46.2	10–400	
Zn	µg/L	116.7	345	35	83.2	10–2900	
Total Cr	µg/L	5.92	16	0.01	5.31		

4. Discussion

Combined drainage systems are the most common in European urban areas, as well as other parts of the world [20–22], since, under ordinary conditions, they are the simplest to construct and operate.

During dry periods, they channel sewage into the WWTPs, while during rainy periods, surface runoff collected in the sewer inlets helps to remove contaminating material (liquid and, to a greater extent, solid) that may have previously been deposited along pipes and other elements of the network. Episodes of intense rainfall pose a problem for WWTPs, since the increased flow implies a significant dilution of the pollutant load they must treat, causing frequent operational problems. Furthermore, when rainfall is very intense, combined sewer overflows often may occur, thus forcing a volume of water with a high pollutant load to be discharged directly into the receiving natural environment due to the impossibility of the WWTP managing such a flow. These CSOs discharge into the environment; therefore, not only untreated runoff water, but also the pollutant load accumulated in the drainage network, along with the sewage generated during that period of time, is discharged as well [9].

One of the most difficult aspects to determine is the nature and intensity of stormwater pollution in a specific location. As already indicated in the introduction, it is known that the first wash generates a flow with a significantly higher pollutant load. This first flush phenomenon is observed more often during both stormwater runoff and CSO events [23] than others, but it must be taken into account that throughout a specific rainfall episode, the collected waters tend to mix over time, so it is more realistic to try to determine the mean concentration of the event. In this work, for each rainfall event, simultaneous samples at five sampling points representatively covering the urban area have been collected using a specific device that allows for the capture of water before entering the combined drainage network. The chemical concentration analyzed in each specific sample depended on several factors, including rainfall intensity, the drained area, and the previous dry period. Therefore, variability in the results obtained for the same event at different sample points is expected. However, by combining the results of these analyses, a composite sample is obtained. This better reproduces the EMC than any individual point (representing the concentration of water that would flow if the drainage network were separative), thus characterizing the overall contaminant potential of a specific event. Table 4 presents the average data for the sampled events, relative to the main parameters considered here as the basis for the discussion. To calculate the averages, in those samples in which a parameter was below the detection limit, the respective limit value was used to avoid underestimations.

Table 4. Mean concentration calculated by events.

Date of Rain Event	COD (mg O_2/L)	N Tot (mg/L)	P Tot (mg/L)
29 August 2024	92.6	12.34	0.672
10 September 2024	78.4	6.14	1.076
29 October 2024	197	7.02	1.86
10 November 2024	135.7	4.68	1.35
4 March 2025	1331.8	5.28	2.26
17 March 2025	126.7	9.25	1.00
25 March 2025	70.7	6.50	0.81
7 April 2025	117.7	5.77	1.00

All but one of these mean values are within those considered in [19] to be representative of urban stormwater concentrations. The singular deviation corresponds to the sampling of 4 March 2025, which is considered an anomaly due to its excessiveness. These anomalies are related to the COD and P_{tot} values, primarily at the sampling points of Pza. España, Tenerías, and, to a lesser extent, Av/Zaragoza. On the other hand, if the EU discharge limit values are considered, half of the stormwater events fall within these maximum values, so they could have been discharged directly into the natural environment without risk of contamination. The other half of the events only exceed the maximum value for COD, because the contents of both N_{tot} and P_{tot} (with the sole exception of the event of 3 March 2024) do fall within the discharge limit established by EU legislation. On the other hand, if the concentrations of the samples are analyzed individually instead of the average values, around half (18 out of a total of 35) meet the EU discharge limit values.

All these results attest that the stormwater samples generated in La Almunia generally present a low contaminant load. According to [24], the inflow waters into the local WWTP have average annual COD contents of 395 mg O_2/L, N_{tot} of 21.26 mg/L, and Pt_{ot} of 2.0 mg/L. Table 3 indicates that, for the stormwater samples analyzed in this work, the respective average contents are 291, 8.03, and 1.38, significantly lower, especially considering that the average values of the WWTP samples include the diluting effect of rainwater and irrigation return contributions.

Figure 3 shows the results of the stormwater sample analysis, grouped by event, in the form of box and whisker graphs. Electrical conductivity has been represented as a descriptive parameter of the global load of dissolved elements, and also the values corresponding to COD, N_{tot}, and P_{tot} as representative parameters of pollution in urban areas.

The electrical conductivity of stormwater exhibits the greatest variability of all the parameters of interest analyzed here. It should be noted that La Almunia is located in a rural area with intense agricultural activity, which involves the frequent circulation of agricultural machinery moving a large amount of dirt, which is deposited on the town's main roads as a result of its traffic. This fact is clearly reflected in the high EC values for the first sampled event (at the end of August), which took place after a prolonged period without significant rainfall and just after the end of the annual agricultural campaign, and also in the marked COD anomaly related to the March 4 sampling, which, combined with a prolonged dry period and low rainfall, coincided with the field manuring season. This has led to the waters from this last event presenting high COD, N_{tot}, and P_{tot} contents, mainly along machinery transit routes (Pza. España, Tenerías, and, to a lesser extent, Av. Zaragoza), implying also a high EC in the analyzed waters.

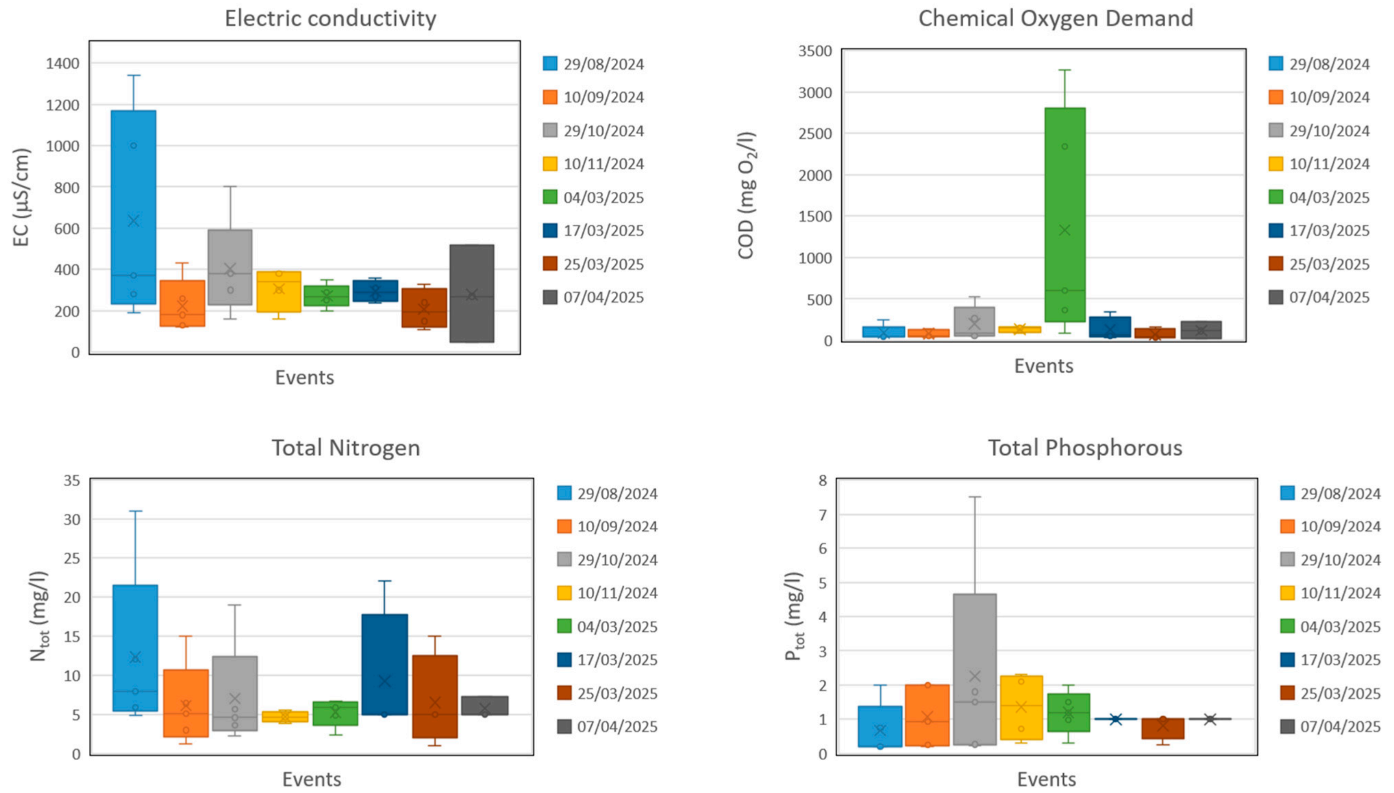

Figure 3. Chemical composition of samples grouped by events.

On the other hand, the variability in the contents of N_{tot} and P_{tot} has also been affected by the washing of bird droppings accumulated on the roofs of the buildings in the oldest part of the town, which is especially marked in the samples collected in Plaza España and Av. Madrid (Figure 4). The effect of bird droppings has been analyzed in monument maintenance and restoration works, which has revealed the contribution of nitrogen and phosphorus compounds to the leachate generated during rainfall events [25]. All of this indicates that the distribution of pollutants in stormwater is also affected by the population's economic activity (in this case, mostly agricultural) and its seasonality, as well as by bird droppings, which mostly nest in the roof areas of the oldest sectors of the population.

In relation to the metal pollution associated with stormwater, it is necessary to indicate that many researchers have attempted to relate the contents of metals in stormwater runoff to the number of antecedent dry days, but this relationship has usually proven to be poor [5,26,27]. In this work, both Cu and Zn were present in samples at levels typical for urban surface runoff, according to [19], as can be seen in Table 2. In fact, both Cu and Zn are within average ranges around 100 µg/L and individual maximum values below 350 µg/L. In general terms, the main sources of heavy metals in stormwater runoff are industries, buildings, particularly roofs with metal elements, vehicles' parts and components, fuel and oils, and metallic structures on roads [28]. In addition, the high metal contents in runoff waters are associated with low pH and high organic matter contents [5], but since these conditions do not exist in the samples analyzed in this work, the analytical values obtained here for Cu, Zn, and Cr are low and do not pose environmental threats that should be taken into special consideration.

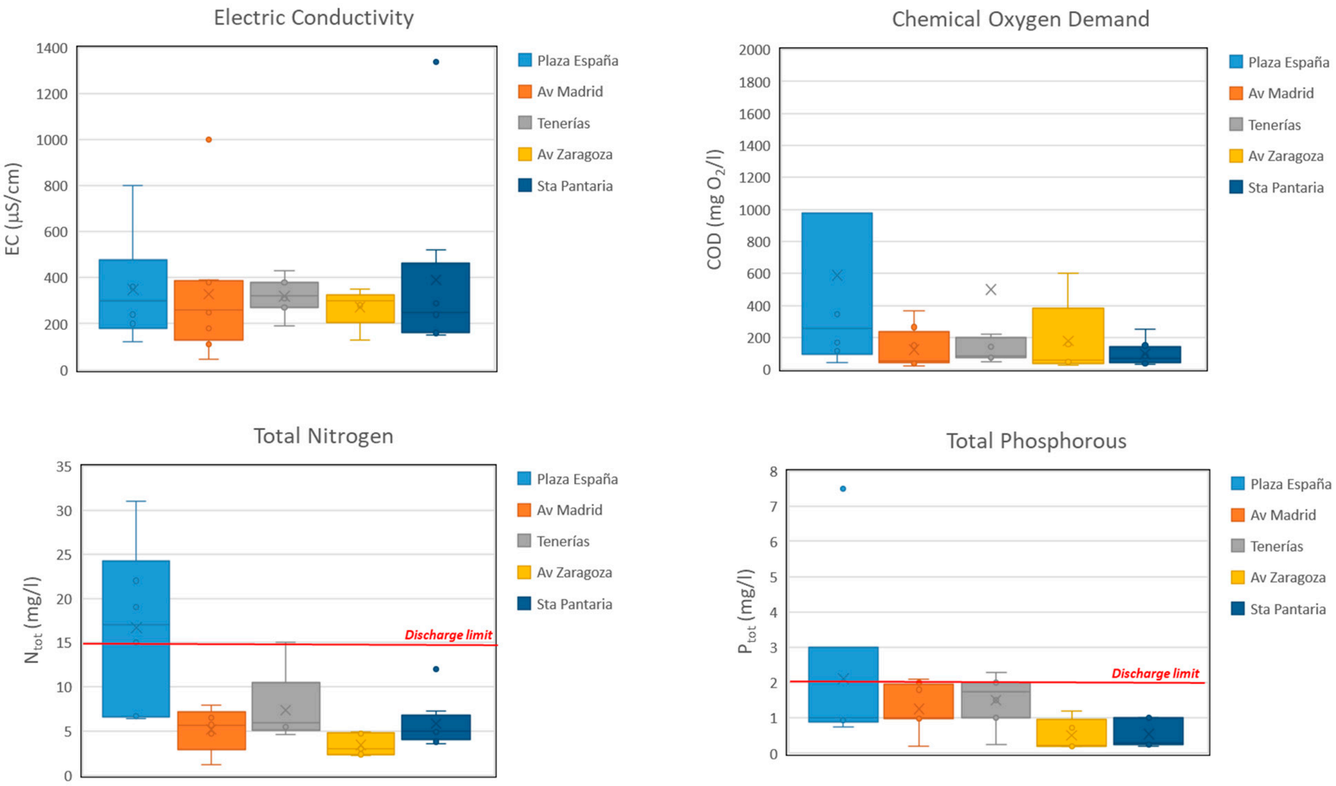

Figure 4. Chemical composition of samples grouped by location.

5. Conclusions

This article evaluates the pollution associated with stormwater in a small town with a combined drainage system. The development of a device to collect stormwater samples allowed for the determination of the chemical composition of the water entering the drainage system of the studied population, simultaneously at five points and for a series of precipitation events distributed throughout the different seasons of the year. In this way, it was possible to evaluate the results both at the level of the rainfall event (creating an analog of the average concentration of the event) and also in relation to the variations associated with the specific location of the different sampling points.

All the results obtained attest that the stormwater samples generated in La Almunia generally present low contaminant loads, but they present a high variability between the different sampled events, in line with the results of similar studies on the subject in the literature. All analytical results obtained for the parameters of interest (mainly COD, N_{tot}, and P_{tot}) are within the usual limits referenced by the US-EPA [19] for urban runoff, and the mean concentration of stormwater calculated for half of the events fell within the discharge limit values established by the European Union, so they could have been discharged directly into the natural environment without the risk of contamination, even in case of a separative drainage network.

The variability between events typically depends on several factors (including the intensity of precipitation and the length of the previous dry period), but in this case, a relationship was found with the timing of agricultural activity; the events with the highest average concentration were those following the intensive transit of agricultural machinery at the times of manuring and harvesting. Furthermore, this temporal circumstance was also reflected in the spatial irregularity of stormwater concentrations, with samples collected on machinery transit routes showing a higher contaminant load. Additionally, this spatial variability was also conditioned by the contribution of the washing of bird droppings accumulated on the roofs of the buildings in the oldest part of the town, so that in these areas of the town, the contents of N_{tot} and P_{tot} in stormwater were higher. The mobilization of heavy metals analyzed (Cu, Zn, Cr) was considered low and did not pose environmental threats.

The main limitations of this study are related to the difficulty in finding clear correlation patterns between runoff concentrations and the variables involved, primarily rainfall intensity and the dry period between events, which operate in opposite directions. This is one of the remaining challenges in this type of study, whose understanding will help inform decision-making regarding stormwater management. However, the results obtained here serve to describe the situation of the population analyzed, but they can be extrapolated to towns with similar characteristics in terms of number of inhabitants and predominantly agricultural economic activity, which are very common in inland areas of countries with temperate climates.

6. Patents

The device has been registered as a utility model in the Spanish Patent and Trademark Office (Ministry of Industry and Tourism, Spanish Government), with publication number ES1314396 and date of approval 23 May 2025.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/w17223294/s1, Figure S1: Location of sample collection points on the La Almunia satellite image.

Author Contributions: Conceptualization, B.R. and A.A.-O.; methodology, P.L.L.-J., A.A.-O., D.A.C. and C.B.H.; validation, A.A.-O. and D.A.C.; investigation, B.R., P.L.L.-J., A.A.-O. and M.A.; data curation, P.L.L.-J. and A.A.-O.; writing—original draft preparation, P.L.L.-J. and A.A.-O.; writing—review and editing, B.R., A.A.-O. and D.A.C.; supervision, B.R.; project administration, B.R.; funding acquisition, B.R. and A.A.-O. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

WWTP	Wastewater treatment plant
CSO	Combine sewer overflow
EMC	Event mean concentration
EC	Electrical conductivity
COD	Chemical oxygen demand

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