Design of a sequential atmospheric deposition sampler for use in remote catchments

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Abstract

A simple sequential (stage) atmospheric deposition sampler has been developed for use in remote mountain catchments. This sampler makes use of wet precipitation channelled to a tilting container in order to activate a sequential sampling mechanism. The sampler is adjustable to collect a series of rainfall samples each representing a defined rainfall depth. The sampler is constructed of chemically stable components and is well suited to the collection of samples in stages for the analysis of the temporal variation in the chemistry of storm events, particularly in remote areas lacking a power supply.

Introduction

Precipitation chemistry research in the mountain catchments of South Africa began in the early 1970s. By 1985 a national working group had been initiated by the CSIR to co-ordinate atmospheric pollution and related research in the heavily industrialised Eastern Transvaal highveld and adjacent areas where the potential for acid rain problems is greatest.

Precipitation chemistry data obtained in South Africa's mountain catchments with an inert sampler (Van Wyk, 1981) and an Aerochem-metrics wet/dry precipitation sampler indicated the essential need to sample precipitation in stages, in order to obtain more information concerning the composition and origin of pollutants (Van Wyk, 1990).

It appears as if the emission and diffusion of pollutants into the atmosphere, and the transport thereof, is more complex in the Eastern Transvaal than was initially supposed (Tyson *et al.*, 1988). To develop a better understanding of atmospheric deposition and its origin, dispersion and composition, it was necessary to develop a simple and efficient sequential (stage) wet atmospheric deposition sampler which is not dependent on an external power source. A sampler designed at the Jonkershoek Forestry Research Centre uses wet deposition to activate the sequence sampling mechanism and this feature allows its use in remote areas where no power sources exist.

The sampler

The sampler is depicted in Fig. 1. A list of components appears in Table 1. The sampler has two basic components, namely the sampling component (A) comprising a rainfall collector and sample bottles and the sequence activator (B) comprising another collector and the tilting mechanism. The sampler can be set to sample rainfall events in stages of any specific depth (e.g. 1 mm, 2 mm or 5 mm stages). This is attained by adjusting the size of the rainfall collector which fills the sequence activator. The sample collector is also adjustable to provide an adequate sample for a given rainfall depth. Both of these collectors are tilted with 4° towards the outlets. Each stage of the rain event is sampled and stored independently and there is no chance of exchange between samples. Possible contamination between samples is a disadvantage of the systems used by Kennedy *et al.* (1978) and Vermette and Drake (1987).

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The sampling device

The precipitation samples are collected in a sample collector (C), which has an adjustable area (Fig. 1). Sample collector C is constructed of a chemically inactive material (stainless steel grade 316). The sample collected then flows through a pipe (D) which is rotated over the inlets of the sample containers (G) by means of the sequence activator. The inlet pipe swivels on bearings (E) so that the operation is carried out with the least friction. The sample flows through a water barrier (F) and is collected in an airtight container (G). The sequence activator moves the inlet pipe (D) to the next sampling container. Once the desired rainfall depth has been sampled in sequence the rest of the sample is collected in a bulk sample container (Y). The water barrier is similar to that used by Likens *et al.* (1967). The water barrier prevents contact with the atmosphere and consequent contamination and/or exchange of substances. As the rain sample flows into the container, the replaced air is exhausted by means of a tube (J) which passes through a water barrier (K).

To change the sample volume, the surface areas of the precipitation collectors (N and C) are adjusted by means of the adjustable lids L and M (Fig. 1). Examples of settings appear in Table 2 and were calculated by means of the following formula:

$$L_e = \frac{V_o \times 1000}{P_r \times W_i}$$

where:

L_e = length of collector (mm)
V_o = volume sequence activator (500 mℓ) or volume of the sample
P_r = precipitation depth to be sampled (mm)
W_i = width of collector (mm)

The catch area of the sample collector (C) is related to the catch area of the sequence activator collector (N), the catch from which activates the next sequence, and this allows one to obtain samples of a specific volume.

The sequence activator

The sequence activator contains a tilting container with a siphon tube, an adjustable pull-rod, an adjustable disk stop and various adjustment points for calibration purposes. The tilting container (O) (Figs. 1 and 2) is filled with water from the rainfall collector for the sequence activator (N). The values in Table 1, calculated from

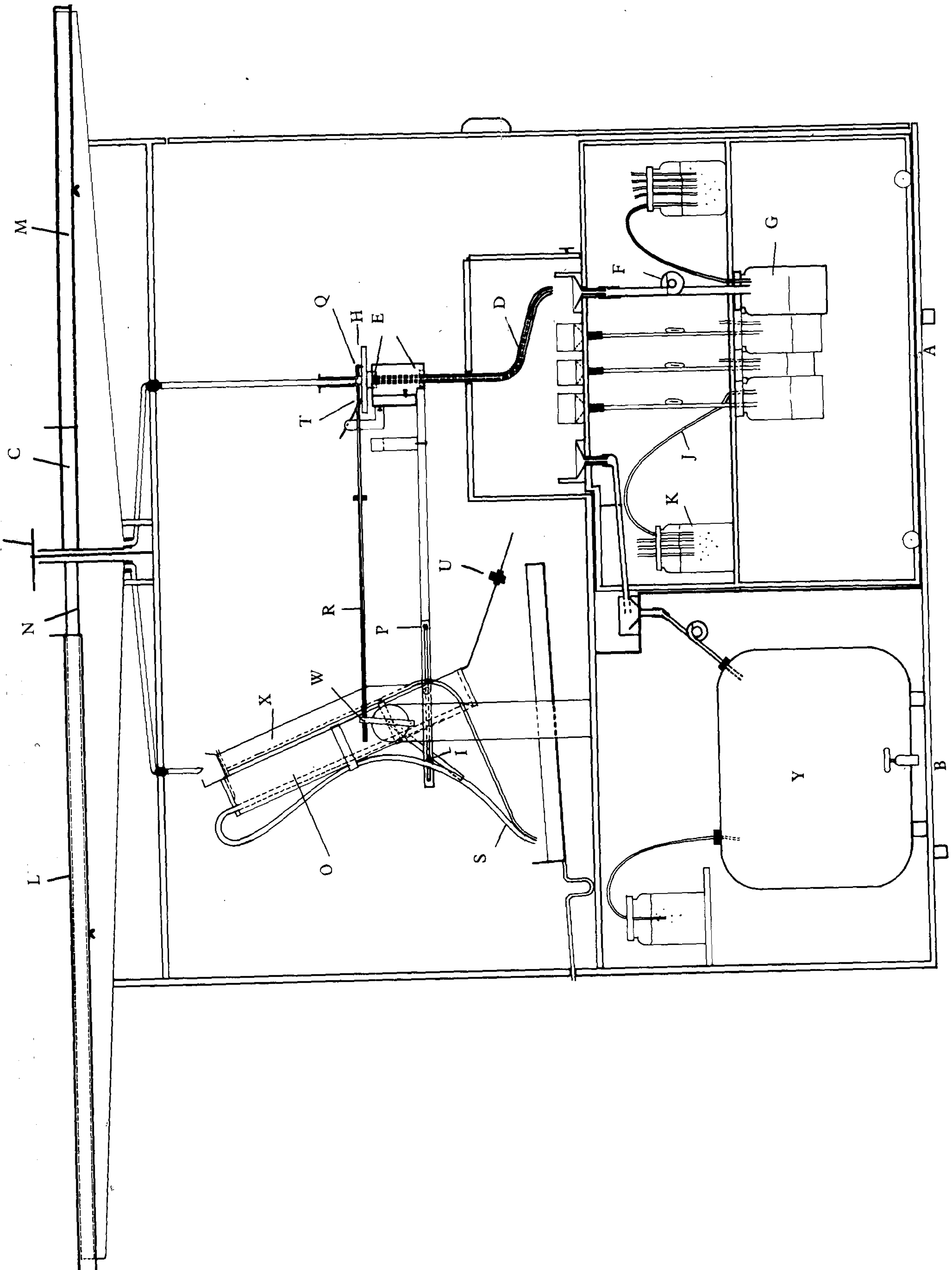

Figure 1
Sequential atmospheric deposition sampler with A the sampling device and B the sequence activator

TABLE 1
LIST OF COMPONENTS COMPRISING THE SEQUENTIAL ATMOSPHERIC DEPOSITION SAMPLER (See Fig. 1)

A - Sampling device
B - Sequence activator
C - Sample collector (stainless steel Grade 316)
D - Sample feed pipe
E - Bearings
F - Glass tubing with vapour barrier
G - Sample container
H - Revolving disk (replaceable)
I - Sequence activator angle setter
J - Air outlet
K - Container with distilled water (vapour barrier)
L - Adjustable cover of rainfall collector
M - Adjustable cover of sample collector
N - Rainfall collector (sequence activator collector)
O - Tilting container
P - Adjustable tilting container range stop
Q - Pull-holes on revolving disk for pull-rod
R - Disk pull-rod
S - Outflow/siphon pipe
T - Disk stop hole
U - Adjustable counter weight
V - Final disk stop mechanism
W - Stroke length adjustment of pull-rod
X - Drip collecting trough
Y - Bulk sample container
Z - Bird perch

TABLE 2
TABLE OF ADJUSTMENT TO SAMPLE DIFFERENT DEPTHS OF RAINFALL WHILE GIVING SAMPLE VOLUME OF 250 mℓ

Rainfall depth (mm)	Sequence activator collector			Sample collector		
	Width (W_i) (mm)	Length (L_e) (mm)	Volume (V_o) (mℓ)	Width (W_i) (mm)	Length (L_e) (mm)	Volume (V_o) (mℓ)
1	800	625	500	500	500	250
2	800	313	500	500	250	250
3	800	208	500	500	167	250
4	800	156	500	500	125	250
5	800	125	500	500	100	250
10	800	63	500	500	50	250

the given formula, are used to adjust the catch area of N and C. By reducing the catch area of the collector (N) only a greater **rainfall depth** can be sampled before the tilting container (O) tilts, hereby moving the sampler onto the next sample. Larger or smaller **sample volumes** can be collected by increasing or decreasing the area of the sample collector (C). Increasing the size of collector (N) without adjusting the sample collector (C) will mean that a smaller rainfall depth is sampled, but that sample size will decrease.

The tilting container (O) of the sequence activator (B) stands at an angle of approximately 23° to the vertical when at rest. This angle is adjustable (adjustable screw I). If set at less than 23° the sequence activator will require more water to tilt, while at a greater angle less water is necessary. When the tilting container (O) of the sequence activator is filled with water its moment (center of gravity) shifts, the container tips and pulls disk (H) of the sampler at the point (Q) by means of a pull-rod (R). Considerable force is generated by the tilting of the sequence activator. With this action the sample pipe (D) is moved to the next sample container. The tilting container (O) comes to rest on the adjustable support (P) and the water flows out through pipe S (Fig. 2). This outflow action changes into a siphon action. The trough X is connected to the sequence activator, which catches the dripping water while in a horizontal position. The moment of the container shifts back as a result of an adjustable counter weight (U) as the container (O) empties during the siphon action. The tilting container returns to its original position while the siphoning action continues until the sequence activator container (O) is empty. While the sequence activator is in a vertical position, the water collected in the trough is discarded. At this stage the disk stop (T) prevents the disk from moving backwards when the pull-rod (R) moves back to its original position. The pull-length of the pull-rod (R) is adjustable at the point W (Fig. 2). This is set when initially calibrating the apparatus and may need adjusting for different disks designed to take different numbers of samples. In Fig. 3 the plan of the disk with the pull-holes (Q) and stop-holes (T) is shown. Interchangeable disks may be used with the number of samples to be collected determined by the number of holes in each disk. The last sample position has a stop mechanism (V) so that the final container collects all of the excess rainfall. A bulk container (20 ℓ) should be used for this. The disk stop mechanism (V) puts the pull-rod out of action by slipping it off the disk. The instrument must be adjusted (calibrated) after each disk change.

Performance of sampler

A prototype of the apparatus designed to take 10 samples was tested under simulated and natural rainfall conditions and functioned well. A more precisely machined prototype has since been manufactured by the workshop of the Weather Bureau and a private engineering company. Performance of this unit may be evaluated from results in Table 3. The unit was set up to sample every 2 mm stage of each rain event. Sample volumes were adjusted and ranged between 250 mℓ and 500 mℓ for different events. The results indicate that the number of samples taken correlates well with size of the rainfall events. The analytes determined (Table 3) show the variability in concentration of the sequential samples. Values are compared with bulk sample data obtained with the Aerochem-metric apparatus imported from the United States of America (Van Wyk, 1990). The standard deviation and coefficient of variation of the sample sizes indicate a small variability in sample volume for various sample size settings (Table 4).

The bird perch (Z) is installed on the side of the sampler to prevent the sample being contaminated by bird droppings.

Discussion and conclusion

The most important features of the sampler are that it does not require a power source, that each sample collected is separated from the next, that the sampler may be adjusted to collect different depths of rainfall, and that this is very simple and can be done by unskilled personnel. Servicing and calibration are also very straightforward. All components of this precipitation sampler can be manufactured from commercially available material and can be assembled with limited workshop facilities. A precision engineered apparatus will, however, give better results.

The sampler is very versatile and could, with minimal modification, be used for various studies where wet precipitation is involved, for example: atmospheric deposition, nutrient cycling, runoff plots, and mist interception studies. Information pertaining to the availability of the apparatus can be obtained from the senior author.

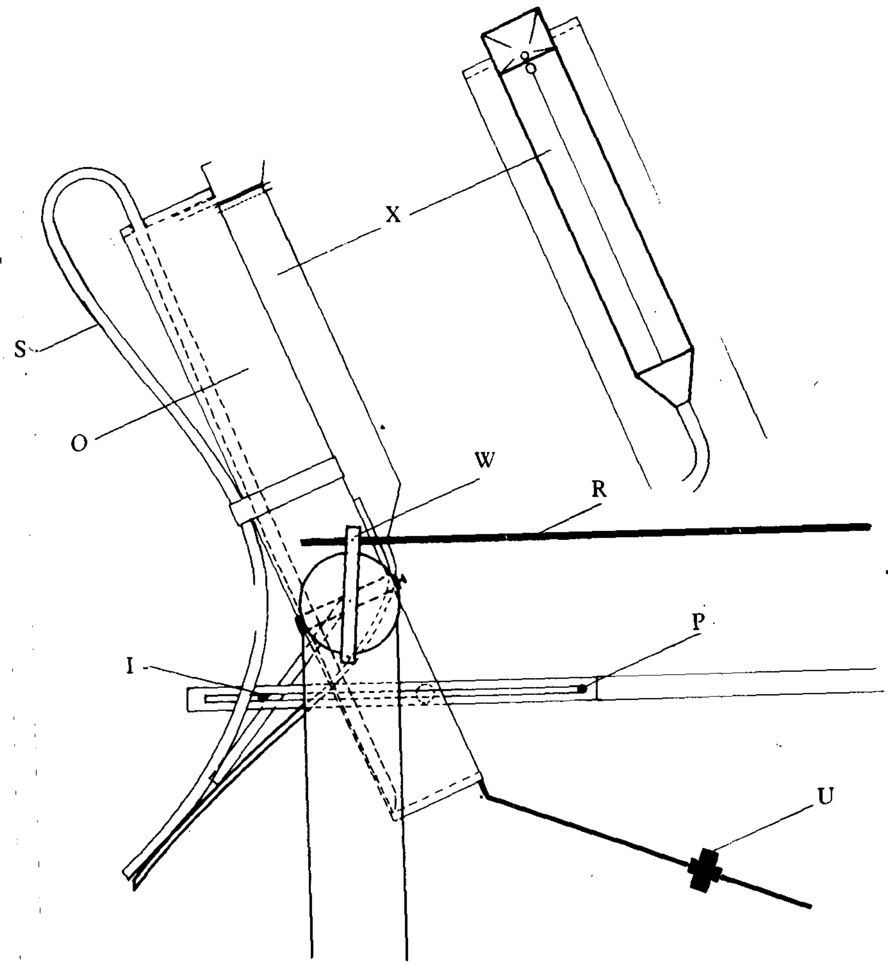

Figure 2
Sequence activator of the atmospheric deposition sampler

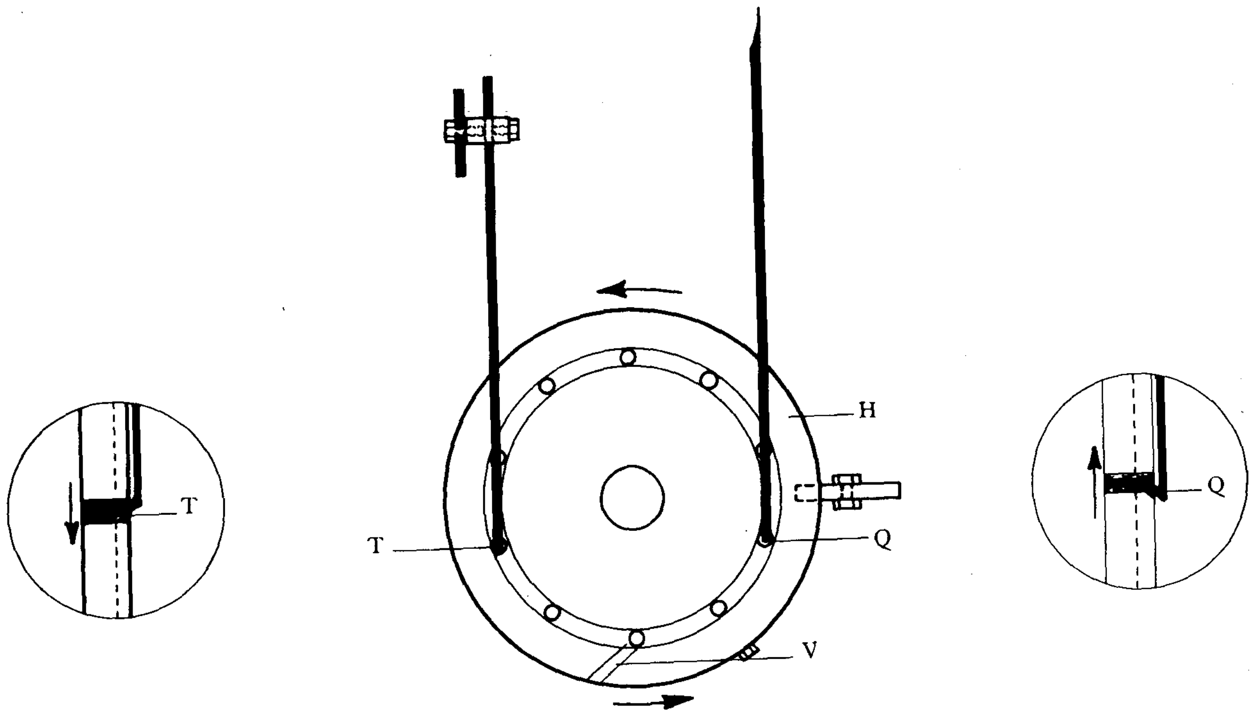

Figure 3
Driving disk of the sequential sampler

TABLE 3

ANALYTES IN WET ATMOSPHERIC DEPOSITION SAMPLES OBTAINED WITH THE SEQUENTIAL AND AEROCHEM-METRIC WET/DRY PRECIPITATION SAMPLERS. THE SEQUENTIAL SAMPLER WAS SET TO SAMPLE EVERY 2 mm. SAMPLES TAKEN DURING RAINFALL EVENTS THAT PRODUCED NINE OR LESS SAMPLES

Rain event: date and total rainfall (mm)	Sample No.	Sampling interval (mm)	Sequential sampler pH	Sequential sampler Conductivity** (μmhos/cm)	Aerochem-metric* sampler pH	Aerochem-metric* sampler Conductivity** (μmhos/cm)
13-03-89 (13,3 mm)	1	0-2	6,33	37,94		
	2	2-4	6,23	7,72		
	3	4-6	6,11	6,88		
	4	6-8	5,80	12,48	5,90	4,20
	5	8-10	6,10	4,11		
	6	10-12	6,05	3,07		
	7	12-13,3	5,89	10,51		
23-04-89 (3,5 mm)	1	0-2	5,03	2,53		
	2	2-3,5	5,02	2,65	6,06	12,45
13-05-89 (9,7 mm)	1	0-2	6,24	57,95		
	2	2-4	6,18	25,42		
	3	4-6	6,16	28,68	5,98	54,01
	4	6-8	6,18	36,99		
	5	8-9,7	6,12	55,53		
22-05-89 (12,5 mm)	1	0-2	6,30	15,12		
	2	2-4	6,40	10,57		
	3	4-6	6,24	6,47		
	4	6-8	6,04	12,23	6,69	8,31
	5	8-10	6,03	7,33		
	6	10-12	5,95	6,40		
	7	12-12,5	5,88	9,17		
02-06-89 (16,9 mm)	1	0-2	5,63	18,47		
	2	2-4	5,57	17,26		
	3	4-6	5,54	12,47		
	4	6-8	5,44	7,86		
	5	8-10	5,37	5,49	5,06	10,88
	6	10-12	5,31	7,23		
	7	12-14	5,20	16,21		
	8	14-16	5,31	17,29		
	9	16-16,9	5,35	11,71		
03-06-89 (5,9 mm)	1	0-2	4,59	19,26		
	2	2-4	4,80	21,76	4,45	19,02
	3	4-5,9	5,08	13,17		

*Bulk wet samples taken with an Aerochem-metrics wet/dry precipitation sampler.

**Specific conductivity at 25°C.

TABLE 4

DISTRIBUTION OF VOLUMES SAMPLED DURING RAINFALL EVENTS USING THE SEQUENTIAL SAMPLER. SAMPLING WAS DONE AT 2 mm INTERVALS AND VOLUMES WERE VARIED FOR DIFFERENT STORM EVENTS

Date	Samples	Mean volume mℓ	Standard deviation mℓ	Coefficient of variation (%)
13-03-89	6	357	24,10	6,75
30-03-89	9	283	9,82	3,47
22-04-89	9	241	13,60	5,64
12-05-89	9	468	26,50	5,66
13-05-89	4	384	3,60	0,94
18-05-89	9	492	6,40	1,30
02-06-89	8	288	10,8	3,75
03-06-89	3	273	14,8	5,42

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