An Automatic Sequential Rain Sampler[1,2]

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ABSTRACT

A sequential rain sampler has been developed that collects up to 70 samples from 35–70 mm of rain. Each sample has a volume of 500–1000 ml and represents 0.5–1.0 mm of rain. After all bottles are filled, any additional rain is automatically discharged. The area of the collector is 1 square meter. All surfaces touched by the rain water, including the bottles used to contain the samples, are polyethylene or Teflon. After every sample, an event mark is recorded on a strip chart; at the first mark, the chart speed increases from 3.8 cm hr^{-1} to 3.8 cm min^{-1}. This provides adequate resolution between event marks for the computation of rainfall rate. If a time reference is provided while the chart is on fast speed, the starting and ending times of individual samples are known within 1 sec.

1. Introduction

The purpose of this note is to describe a new automatic rain sampler. This device was designed 1) to provide sequential samples of convenient size for chemical analysis, each sample representing 1.0 mm of rain or less, and 2) to time accurately the beginning and end of each sample.

Sequential sampling of precipitation has been used for the past decade or so as a way of observing wet deposition of radioactive bomb debris and other materials. Analyses of sequential samples for various chemical, radiochemical and biological materials have revealed large variations of rainwater contaminant concentrations during rain periods. These variations occur very rapidly in convective rains, and they usually bear some relationship to changes in rainfall rate. This relationship is usually approximately inverse, with high concentrations occuring in light rain and vice versa.

Whenever the same set of sequential samples is analyzed for more than one constituent, the concentrations of the various components usually are found to vary in a somewhat parallel manner with time.

The observed variations of concentration and rainfall rate in individual rains have been attributed to a wide variety of physical mechanisms by various investigators. A number of recent authors (Hicks, 1966; Storebö, 1968; Gatz and Dingle, 1971) have suggested that observed concentration-rainfall rate relationships can often be attributed to the scavenging mechanism of cloud droplet nucleation. There is a need for observations of additional rainwater constituents, particularly ones that occur on particles of particular known sizes, to see whether concentration profiles can be used to identify scavenging mechanisms.

Sequential sampling is also a valuable observational tool in connection with tracer experiments on precipitation systems. Comparison of "natural contaminant" concentration profiles with those of tracers injected at known times and places may in time offer a means of specifying the mechanisms and efficiencies of aerosol scavenging in clouds.

In any sequential sampling program, it is desirable to operate several samplers, separated horizontally and, if possible, vertically. This procedure would significantly improve our ability to observe contaminant variations

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[2] This work was performed under the auspices of the U. S. Atomic Energy Commission.

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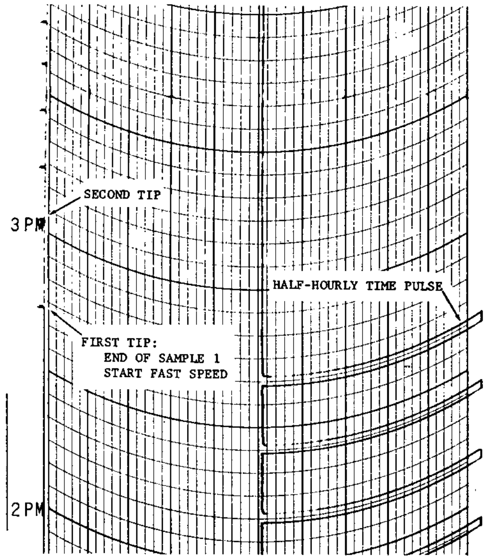

FIG. 1. Typical strip chart, showing bottle change event marks, half-hourly time marks, and a change in chart speed from slow to fast.

in both time and space, and their relationship to the precipitation fileld. Such observations should form the basic framework of any field research program to study scavenging.

The logistics of sequential sampling at multiple sites are aided considerably by automatic sequential samplers. Fewer people are needed to conduct the program, and one does not have to keep a crew on alert when rain threatens.

Automatic sequential rain samplers, using completely mechanical methods of sample changing, have been reported previously (Saucier *et al.*, 1965). Some features of earlier samplers have been incorporated into the one described here.

TABLE 1. Design features.

Collector area	1 m^2
Sample volume	500–1000 ml
Rain depth per sample	0.5–1.0 mm
Maximum number of samples	70
Rainfall corresponding to 70 samples	35–70 mm
Recording features	Event mark after every sample
	Fast chart speed (3.8 cm min^{-1} during rain
Time resolution	1 sec
Power requirement	115 V ac, 20 W
Dimensions	1×1×2 m
Weight	91 kg (200 lb)
Materials	Aluminum angle frame
	Plywood sides
	Aluminum funnel
	Water contacting surfaces are polyethylene or Teflon
Cost	$2000

2. Design features

Table 1 summarizes the sampler's main features. This section discusses some of the considerations that led to their specification.

Sample volume V (cm^3), collector area A (cm^2), and rainfall per sample D (cm) are related by

$$V=AD.$$

A sample volume of 500–1000 cm^3 (variable by mechanical adjustment) was chosen to provide enough water to perform a number of different analyses on the same sample. Then A (1 m^2) was chosen to provide a reasonably small D(0.5–1.0 mm) with a funnel of convenient size in terms of portability and cost. The maximum number of samples (70) was chosen to allow for complete collection of most individual rains using a shelter about the same size as the collecting funnel.

A strip chart event recorder is used to record each bucket tip so that the beginning and ending times of each sample can be determined accurately. Half-hourly time marks are provided by a pen and a synchronous clock. Before rain the chart runs at 3.8 cm hr^{-1} (1.5 inch hr^{-1}) to conserve chart paper. The first bucket tip actuates the fast chart drive (3.8 cm min^{-1}) which provides the time resolution needed to compute event times to the nearest second. This accurate timing, together with the measured sample volumes and the collector area, permits calculation of the rainfall rate for each sample. A portion of a typical chart is shown in Fig. 1.

The decision to use ac power was based primarily on convenience of recording and automatic sample sequencing. The use of ac power reduces the possibility of sampling at remote locations, but this is not very feasible anyway because the sampler's size and weight require heavy equipment to move it about and because we need to get to it easily for servicing before and after rains.

To minimize alterations to the sample through removal or addition of trace substances by surfaces that touch the rain, these surfaces are all polyethylene or Teflon.

3. Sampler operation

The operation of the sampler is illustrated in Figs. 2 and 3. Rain falls into the funnel and drains into one side of the tipping bucket. When enough sample accumulates, the bucket tips and the water is channeled through one of the revolving arms (number 1, say) and into a sample bottle. At the same time a switch is actuated to advance revolving arm 2 into a position over an empty bottle. The first bucket-tip also records an event and actuates the fast chart drive. When the bucket tips back again, another event is recorded, the second sample goes through arm 2 into the bottle, and arm 1 is advanced to a new bottle for the third sample. This sequence

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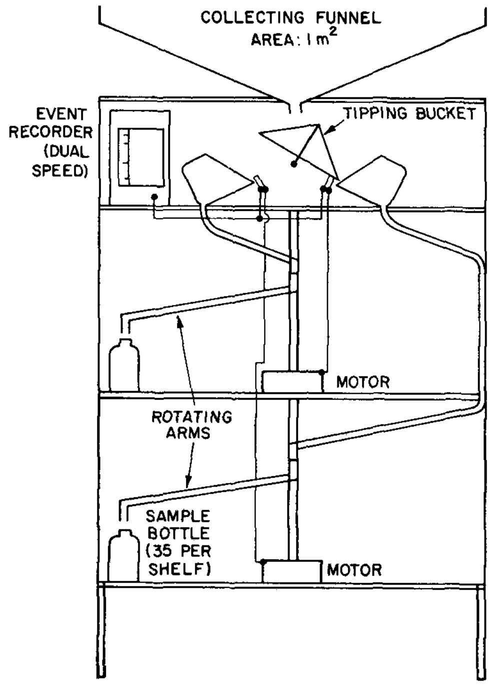

Fig. 2. *Diagram of sampler operation (see text for details).*

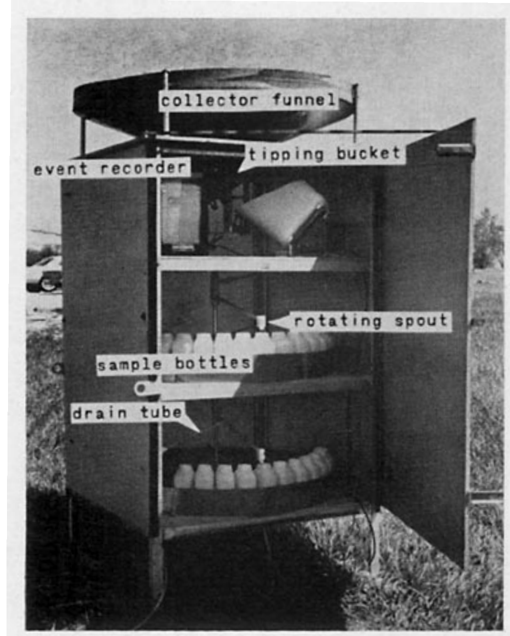

Fig. 3. Photograph of sampler showing main components.

continues until the rain stops, or until all bottles are filled. After all bottles are filled, the rotating arms remain in position over drain bottles, through which any subsequent rainwater is drained away. The chart drive remains on fast speed until manually reset.

4. Advantages and disadvantages

With respect to other methods of collecting rain samples sequentially, this sampler's main advantage is its ability to operate unattended. Its advantages with respect to previous samplers of the same type are that 1) it can collect more samples, and 2) it can determine sample times more accurately.

The sampler's disadvantages are 1) its rather high cost, and 2) certain limitations on field siting, owing to its size, weight and power requirements. With respect to a manned sampling station, there is the additional disadvantage that advancing to a new sample must always await the collection of a full sample. At a manned station one could decide to change samples on the basis of observed meteorological conditions.

5. Example

On 4 September 1969 the sampler collected 21 samples of 500 ml volume each from a convective shower that produced 10.2 mm of rain. Fig. 4 shows the variations of rainfall rate and the lead, copper and zinc concentrations in the collected samples. The concentrations are similar to those observed elsewhere. However, it is possible that dust accumulated in the collector funnel

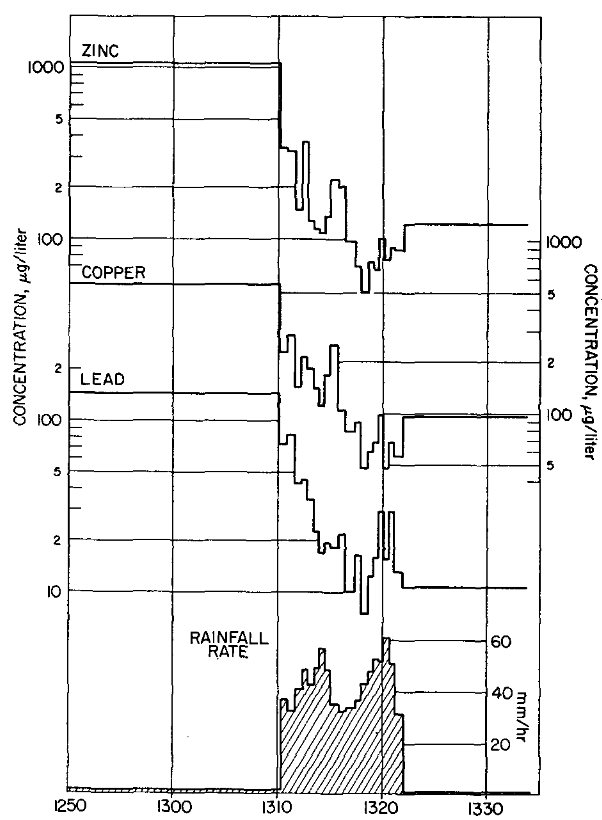

Fig. 4. Variations of rainfall rate and metal concentrations in rain of 4 September 1969.

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by dry deposition may have gotten into some of the samples. Therefore, these data are included only to show the degree of resolution that can be obtained using the sampler.

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