The ALOHA Sampler – An Alternative to Traditional Surface Water Sampling

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DOI: 10.62178/sst.005.008

ABSTRACT

The Aloha sampler is an innovative new simple sampling tool to effectively collect and combine increments from dynamic liquid one-phase (and some two-phase) systems. It is extremely inexpensive and very cost-effective in use and delivers superior fit-for-purpose representative samples.

1. Introduction

Representative sampling of surface water is far from trivial. Distributional heterogeneity demands collecting multiple increments, integrating across and/or in depth the water target in question. In addition to traditional methods such as the isokinetic sampler, a new device, the Aloha Sampler, can more easily be employed in situations where suspended sediment is not a concern. Dip sampling (grab sampling) at the edge of surface water is the least representative method and should be avoided.

2. Background

The Theory of Sampling (TOS) provides a comprehensive approach to representative sampling. Sampling tools are an important component of designing reliable sampling protocols; optimal sample mass and the appropriate number of increments for a composite sample will not provide a representative sampling if the tools are incorrectly designed or utilised. It has been estimated that 75% of all sampling tools are incorrectly designed with the result that: “enormous research is mandatory in order to develop correct sampling systems for monitoring the environment [1].” Correct sampling tools must enable an equi-probabilistic selection of all particles (molecules) at the randomly chosen increment location. Another important role of correct sampling tools is the ability to “reach” into the material being sampled, thus making all the material “available.”

Full availability is a critical success factor to make inferences from the analytical result back to the material in question (in TOS called the lot, and called the “decision unit” in EnviroStat’s approach). This criterion has been formulated as the Fundamental Sampling Principle (FSP), see, for example, DS 3077 (2013)[2].

These two aspects, sampling tool correctness and FSP, are not the only design considerations. Some other important considerations for sampling tools are:

- durability
- easy to clean or decontaminate (if the tool is not disposable)
- easy to use (eliminate operator-induced errors)
- easy to maintain
- inert (does not interact with or contaminate the sampled media)
- maintain analyte integrity (eliminate adsorption, oxidation, leaching)
- efficient to collect and combine increments (to form composite samples)

The potential list of design criteria is too large to address here in full—it is always a function of the material sampled, environmental conditions and the analyte of interest.

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3. Sampling of surface waters

There is a lack of sampling tools that meet the requirements of TOS for sampling of surface waters. Most surface water samplers are discrete point samplers (hand-held or weighted container samplers) and are typically some type of bottle that is opened and filled at one discrete point. These include dippers, lathes, using the sample container as the sampling device, and Van Dorn/ Kemmerer type (Figure 1). All of these types of samplers do not adequately address the inherent distributional heterogeneity of the decision unit.

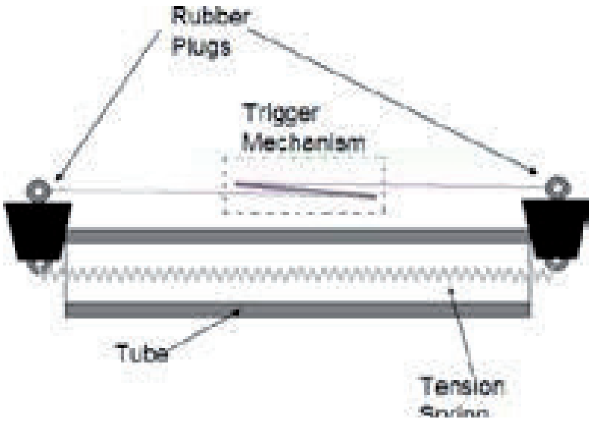

Figure 1: Generic design of Van Dorn/Kemmerer type sampler.

Sampling of surface water is always problematic due to its dynamic nature, especially since the composition changes with respect to both time and space. Examples of dynamic systems are industrial conduits, canals, lakes, rivers and oceans. The difficulty of sampling these systems is well recognised, alas very little has been done to develop tools and techniques to better represent such dynamic systems. The New Jersey Field Sampling Manual states: "Liquids, by their aqueous nature, are a relatively easy substance to collect. Obtaining representative samples, however, is more difficult. Density, solubility, temperature, currents and a wealth of other mechanisms cause changes in the composition of a liquid with respect to both time and space. Accurate sampling must be responsive to these dynamics and reflect their actions [3]".

In one surface water study[4], it was concluded that for individual samples drawn at 10-minute intervals (grab samples), the average variability (change in concentration between consecutive samples) was 60%—and as high as 700% for an individual result. This large variation on such a short time scale makes characterisation of surface waters virtually impossible if based on grab sampling.

In the same report it was also stated that the misclassification rate of water quality was: 33%, 64% and 71% for each of three study years, respectively (% estimates are relative sampling variability (RSV) measures, as described in DS 3077).

The Aloha Sampler (Liquid Sampler Patent 7571657) was developed to address these concerns by an operational mode that will allow more representative liquid sampling. The basic parts of the Aloha Sampler are an aperture cover (lid), and a receptacle for the liquid. The aperture cover has two holes, located along a diameter, that allow the liquid to flow into the receptacle when the sampler is submerged into liquid (Figures 2 and 3). The placement and size of holes allow for an approximate one minute fill rate if the holes are vertically aligned. If the Aloha Sampler is rotated slightly the fill rate increases to approximately two minutes. This gives the sampler flexibility to control the rate of liquid uptake.

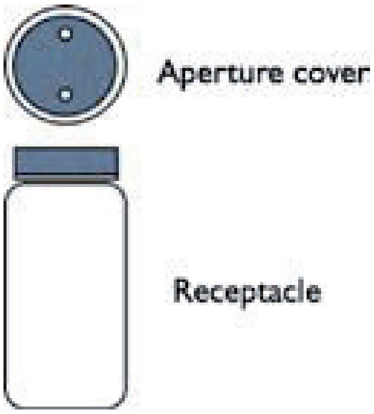

Figure 2: Aloha Sampler side and top view (Liquid Sampler Patent 7571657).

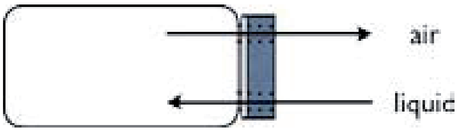

Figure 3: Basic operation of Aloha Sampler (Liquid Sampler Patent 7571657).

Figure 6: The Aloha Sampler in operation. Note air bubble leaving the upper hole in the aperture cover.

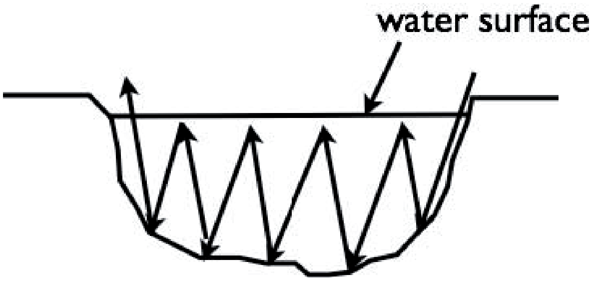

Figure 4: Continuous sampling path to represent a stream section without interrupting the sampling operation.

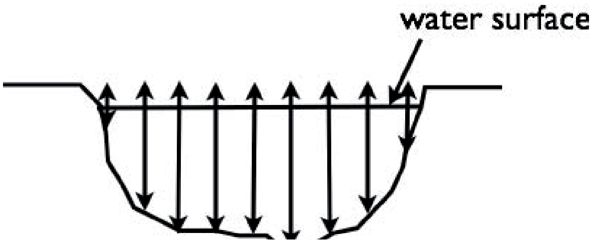

Figure 5: Collection of multiple vertical increments to form an integrated sample (composite sample).

The Aloha Sampler can be used in a continuous mode (sampler not removed from the liquid during sampling) (Figure 4), or non-continuous/intermittent mode (sampler removed from the liquid between increment sampling deployment locations) (Figure 5).

An example of a continuous operation would be sampling from a point on the shore of a river, out ten feet from the shore, from the surface to the bottom in one continuous motion, never breaking the surface of the water during collection. An example of a non-continuous operation would be sampling the length of a river where the Aloha Sampler is inserted in and removed from the river at each increment location (partially filling receptacle at each increment location). Both modes result in a reliable sample. The Aloha Sampler can be used to collect spatially and/or temporally integrated samples [5]. This allows great flexibility for either type of deployment. If the decision unit is small enough, a continuous sample can be easily collected. For larger decision units, a non-continuous sampling method may be desired due to the fixed filling time of the Aloha Sampler. Continuous sampling of liquids typically provides a more representative sample if the logistics allow integration of the entire decision unit.

Figure 7: Use of the Aloha Sampler with an extension pole.

To use the Aloha Sampler, simply submerge the device horizontally with the two holes aligned vertically (one above the other) to the desired depth of the liquid at a constant transit rate. The liquid will flow in the lower hole, and the air will escape through the upper hole (Figures 3 and 6). Once a vertically integrated increment is collected at a single location, move to the next location and take another increment etc. The transit rate, depth of liquid, fill rate and number of vertically integrated increments must be considered individually for each case, but it will always be possible to obtain a meaningful, optimised sample. Some pilot experimentation may be necessary to determine the ideal timing for specific cases—nothing could be easier.

The Aloha Sampler can also be attached to a pole to access hard to reach areas, Figure 7. Once the sample is collected, the Aloha Sampler aperture cover is removed and a solid cover is placed on the sample bottle. The sample is then prepared and stored in the same way as any other type of liquid sample. The Aloha Sampler can be sterilised for the collection of bacteria.

The Aloha Sampler has been used in Hawaii to collect data from construction activities to determine impact to nearby streams.

Multiple samples (replicate sampling) were collected for a specific project to determine the reproducibility of the Aloha sampling approach. RSV (%CV) is quite satisfactorily low for this type of sample collection (Table 1 and 2). These samples were collected using the Aloha Sampler on a pole (Figure 7).

Integrating a sample across the full width and depth of a stream is essential for collecting a representative sample. Cross-sectional variation in contaminant concentration is well documented — surface grab samples collected at a single point have been shown to underrepresent suspended sediment and sediment-associated constituents such as phosphorus, iron, and manganese by 20–60% compared to depth- and width-integrated samples [6,7].

One common workaround is to sample at a point sufficiently far downstream that the stream is assumed to be fully mixed. Various rules of thumb exist for estimating this distance. For high-gradient mountain streams with significant bed roughness and turbulence, complete lateral mixing occurs at approximately 25 stream widths downstream of a discharge point [8].

Table 1: Lihue Mill Bridge, Kauai, Hawaii, 5 November 2013. Owen Environmental, Kalaheo, HI.[2]

	Time	pH	Dissolved oxygen (%)	Total suspended solids (mg L^{-1})
Rep. 1	9:11	7.07	76.0	12
Rep. 2	9:14	6.96	75.5	13
Rep. 3	9:16	6.95	75.8	12
Mean		-	75.8	12.3
RSV (%CV)			0.3	4.7

Table 2: Lihue Mill Bridge, Kauai, Hawaii. 31 October 2013. Owen Environmental, Kalaheo, HI.[2]

	Time	pH	Dissolved oxygen (%)	Total suspended solids (mg L^{-1})
Rep. 1	11:11	7.07	73.9	13
Rep. 2	11:13	7.15	74.7	12
Rep. 3	11:19	7.08	72.9	14
Mean		-	73.8	13
RSV (%CV)			1.2	7.7

For slow-moving, lowland, or gently meandering streams — where turbulence is low and the transverse mixing coefficient is reduced — mixing distances of 50 to 100 or more stream widths are commonly required [9]. The United States Geological Service (USGS) characterizes this more broadly, noting that lateral mixing is generally complete within a few kilometers downstream [10].

There are, however, serious practical problems with relying on downstream mixing as a substitute for integrated sampling. First, a suitable and accessible sampling location may simply not exist at the required distance. Second, and more fundamentally, the mixing-zone assumption breaks down wherever the contamination is not a single, well-defined point source. In industrial areas, stormwater runoff zones, agricultural landscapes, multiple diffuse inputs enter the stream at different locations and different times. Under these conditions there is no defined mixing zone, and complete lateral mixing cannot be assumed at any fixed downstream distance. Sampling at a single point under these circumstances does not represent the stream — it represents only one location in a heterogeneous cross-section. This is the bane of grab sampling of solids, only here in the liquid realm.

Therefore, it is preferable to collect a depth- and width-integrated sample at the actual point of concern, rather than assume against all odds the stream will become well mixed somewhere downstream.

4. Comparison to Other Stream Samplers

The Aloha Sampler is not designed to represent suspended particulate matter larger than 62 µm. Sampling particles above this size requires a more specialized device known generically as an isokinetic sampler. The underlying sampling concept is similar, but the isokinetic sampler includes a nozzle at its intake that is designed to match the velocity of the entering water to the ambient stream velocity.

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[2] Total suspended solids by Method SM 2540 D, Dissolved oxygen and pH by YSI ProPlus Multi-parameter WQ Meter

Because the flow is not accelerated or decelerated at the nozzle entrance, the sample accurately represents suspended particulate matter of all sizes. The relationship between intake velocity and sediment concentration for isokinetic and non-isokinetic collection of water samples that contain particulates greater than 0.062 millimeters is described in [11].

When water accelerates as it enters a nozzle or open container, fine particles — which have less inertia — are pulled into the sampled flow more readily than larger particles, which are largely unaffected. The result is an overrepresentation of fine particles relative to coarse ones. Conversely, when water decelerates as it enters the sampler, fine particles deflect away with the slowing flow while larger particles carrying too much inertia to change course in a similar manner, continue into the container and become overrepresented (Fig. 8). This principle applies to all sampling devices, including automated samplers using pumps.

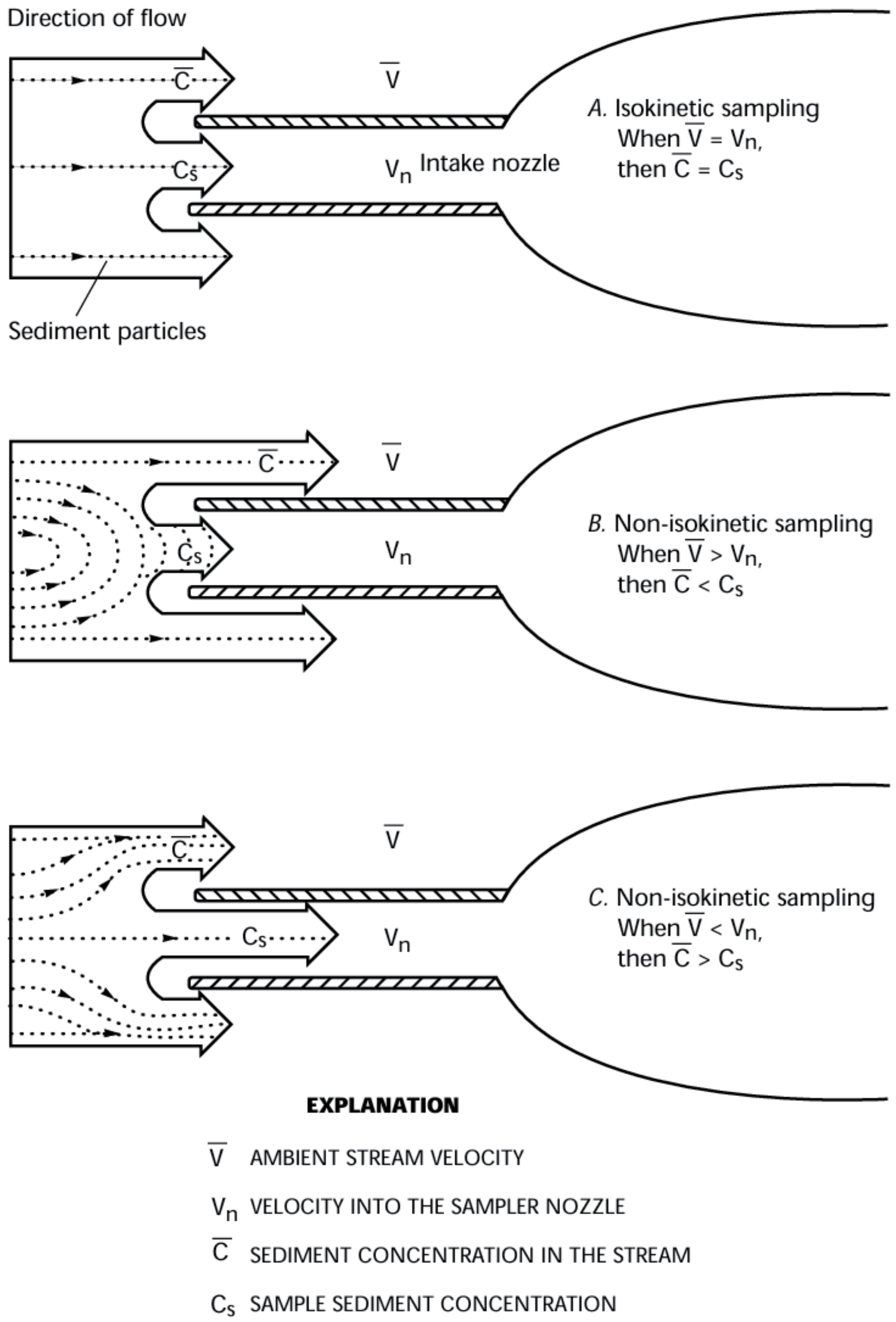

Figure 8: Illustration of non-isokinetic sampling copied from: Wilde, F.D., Radtke, D.B., Gibs, J., and Iwatsubo, R.T. (eds.). National Field Manual for the Collection of Water-Quality Data, Chapter A4: Collection of Water Samples. U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Chapter A4. Reston, VA: USGS, 1999 (revised). Figures 4-1, p. 27.

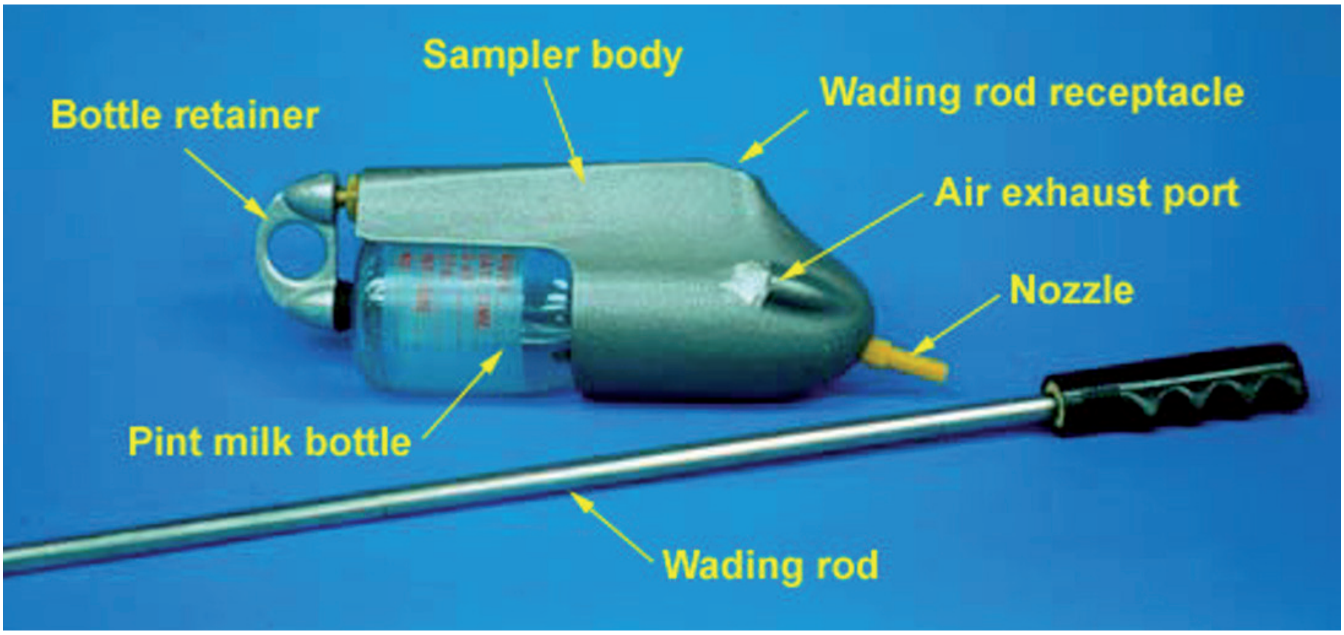

Figure 9: Example of isokinetic sampler. DH-48 Suspended Sediment Sampler. https://water.usgs.gov/fisp/docs/Instructions_US_DH-48_001010.pdf

A related issue arises once the sample container is full or nearly full. At that point the sampler must be removed from the water stream. Leaving it submerged after it has reached capacity introduces its own bias: fine particles, having little inertia, can be swept back out of the container and returned to the stream, while larger particles tend to settle and remain. The net effect is overrepresentation of coarse material relative to fines — the same directional bias as non-isokinetic sampling.

The isokinetic sampler functions correctly only in flowing water, where the nozzle can be oriented to face the current. In still or very slow-moving water — such as lakes, lagoons, and low-gradient ponds — ambient velocity is insufficient to establish isokinetic conditions, and the device behaves essentially like the Aloha Sampler, losing its size-representativeness advantage. While an isokinetic sampler can technically substitute for the Aloha Sampler in any setting, it is more complex to deploy and is generally unnecessary where only fine, or dissolved-phase constituents are of interest.

The USGS introduced the DH-48 isokinetic sampler (Figs. 8, 9) in 1948 [12], and this particular model remains in use today. In the decades since, the USGS Federal Interagency Sedimentation Project has developed numerous additional models suited to a wide range of specific stream depths, velocities, and sampling objectives [13].

5. Bottom Line Comparison

Full stream representation, including suspended material: The isokinetic sampler is the only appropriate choice. It is the only device capable of accurately representing suspended particulate matter of all sizes across the full stream cross-section, provided the stream has sufficient velocity to establish isokinetic conditions.

Stream representation, excluding suspended material (dissolved phase): Either the Aloha Sampler or an isokinetic sampler will work. Because any suspended material collected is filtered out prior to digestion and analysis, sampling bias with respect to particle size is irrelevant for dissolved-phase determinations. Depth- and width-integrated collection is always important for spatial representativeness.

Non-representative grab sampling: A dip sample (grab sample) collected at a single location only represents one point in time and space. It does not represent the stream cross-section and is inherently incapable of characterizing suspended material. Despite these significant limitations, it unfortunately remains the most common sampling approach in practice [14], despite ~70 years of the Theory of Sampling (TOS). Except for the isokinetic sampler, water sampling is not immune from inspiration and guidance from the Theory of Sampling (TOS), ibid.

6. Conclusion

The Aloha Sampler is a promising new tool to effectively collect and combine increments in a dynamic liquid system, producing highly flexible, problem dependent samples with very low sampling variability. It is extremely inexpensive in fixed capital outlay and very cost effective to implement and use.

The Aloha Sampler produces fit-for-purpose samples over a wide range of hitherto difficult-to-sample decision units. The Aloha Sampler is a significant improvement over commonly used sampling approaches and equipment targeting surface waters in a wide range of situations.

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