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TECHNICAL NOTE

A NEW DEVICE FOR SAMPLING WATERS IN SHALLOW ECOSYSTEMS

A. GÓMEZ-PARRA*, J. M. FORJA and D. CANTERO
Departamento de Química Física, Facultad de Ciencias, Universidad de Cádiz, Apdo.
40 Puerto Real (Cádiz), Spain

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Abstract—A set of equipment has been designed to take water samples by aspiration at varying depths in shallow ecosystems. The depths sampled can be freely selected within a range of accuracy of 1 cm. The equipment is portable and can be handled from a boat or from the shore, at points up to 20 m away from the sampling location.

A study was made of the accuracy of temperature and dissolved gas content of samples obtained using this device. With respect to the gas analysis, there was no serious loss of gas from the samples as long as they aspirated under a reduced pressure <400 mm Hg. This system enables the collection at a rate of $10.4\,\mathrm{l\,h^{-1}}$ when the apparatus is placed about 2 or 3 m above the surface of the ecosystem under investigation. The error which occurs in the temperature reading is a function of the differences in temperature between the mass of water sampled and the area surrounding the intake tubes. For differences of around 1°C the error is <0.1°C.

Some modifications of the equipment are also suggested in order to simplify the operations necessary to take samples for dissolved gas measurement. Also proposed is a system of on-line filtration useful for quantitative phytoplankton or suspended solid content determinations in the samples.

Key words—water sampler, shallow ecosystems, dissolved oxygen, temperature, ecology

INTRODUCTION

Sampling is one of the first difficulties encountered in the study of many littoral regions, such as coastal lagoons and salt-marshes. These ecosystems are very shallow (generally under 5 m), so that the processes of matter-transfer through water–air and water–sediment interfaces are often very intense (Hune, 1975). These processes determine the occasional appearance of vertical gradients in the chemical and physical-chemical characteristics of the medium (Dorey *et al.*, 1973; Grasshoff, 1975). The study of these phenomena is of great interest, not only from an ecological point of view, but also for an understanding of how the biomass develops and changes (SCOR/UNESCO, 1980). It is precisely this last aspect which has made it possible to utilize these zones for different types of aquaculture.

The shallow depth of many of these ecosystems makes it impossible to employ the devices normally used in oceanography (Nansen, Niskin and other bottles) to sample at varying depths. The large size of these, determined as it is by the volume of water to be collected, would make it difficult to accurately assign a given depth to the sample obtained.

This paper describes a device specially designed to take water samples in such ecosystems at up to six different depths, which can be freely selected. The apparatus is based on an original idea of MacKereth (1963) and may be used either from a boat or from land. In the second instance, this may be at a distance of 15–20 m from the sampling site. It is cheap and simple to build since most of its components are readily available commercially. Reference is also made to various tests carried out to check for any possible alteration of the dissolved oxygen content and the temperature of the samples obtained using this device.

DESCRIPTION OF EQUIPMENT

The equipment is composed of three basic parts; (1) a vacuum device, (2) the tubes for extracting the samples, with the mechanism for locating them in the chosen sampling site, and (3) the sample-collecting unit.

Vacuum device

Although a conventional vacuum pump may be used, the need to operate the equipment in places where no electric grid is available made it necessary to build an apparatus which could work with a 12 V battery. This device consists of a car starter-motor which belt-drives the fuel oil compressor from a diesel engine (Fig. 1a). Vacuum is obtained by connecting the sample-collecting unit to the compressor air inlet. The equipment develops 72 W and thus, when pow-

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*Present address: Instituto de Ciencias Marinas de Andalucía (C.S.I.C.) 11510 Puerto Real (Cádiz), Spain.

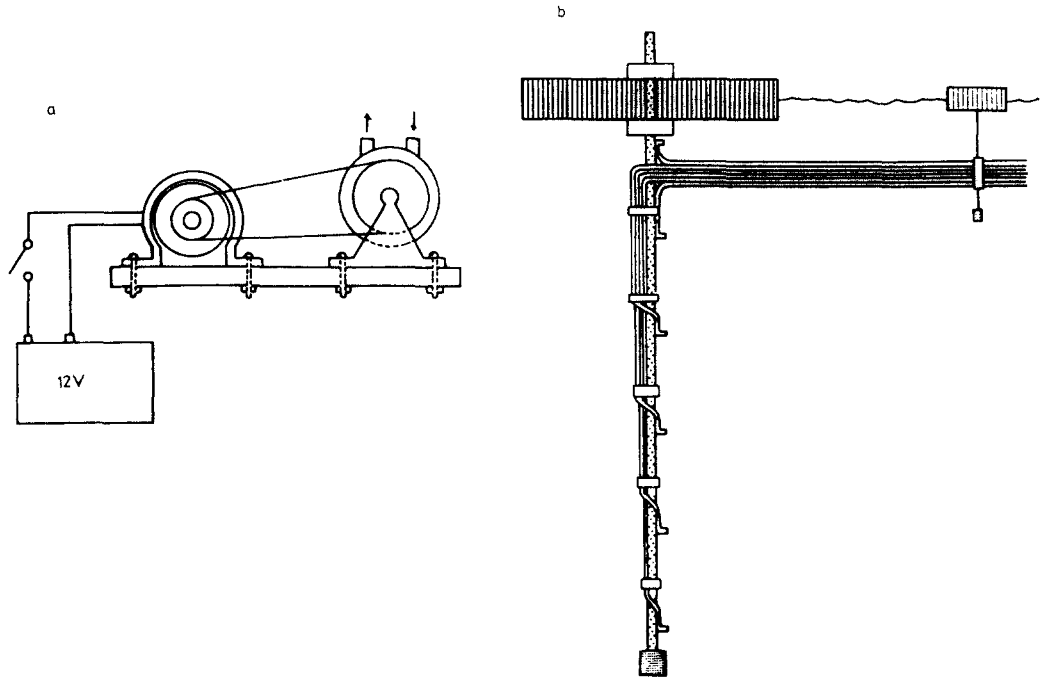

Fig. 1a. Vacuum device; b, sample collector.

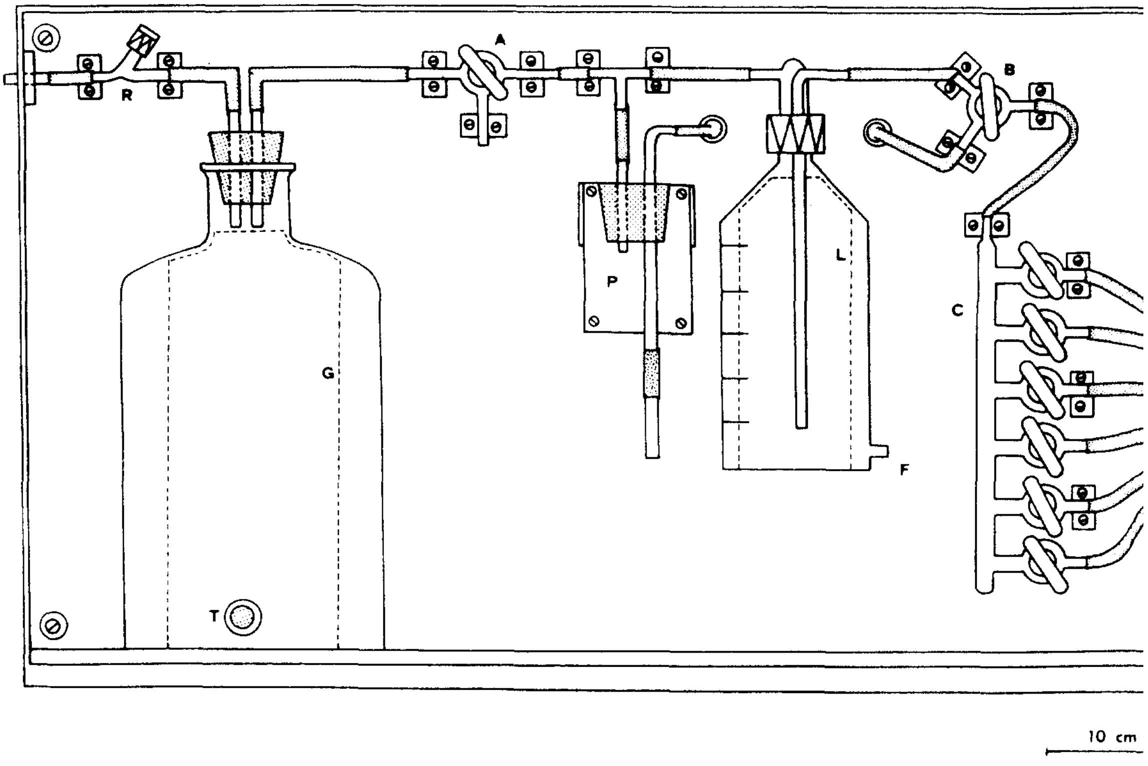

Fig. 2. Sample-taking unit (see text for legend).

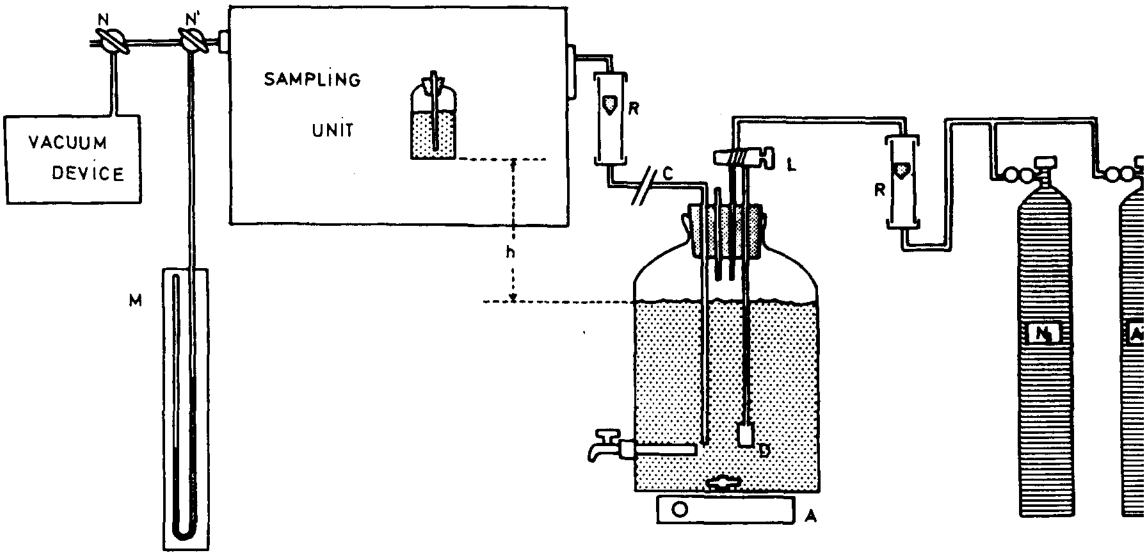

Fig. 3. Device for determining alteration of dissolved gas content in samples taken with this equipment: (A) magnetic agitator, (C) intake tubes, (L) parallel-way valve, (N and N′) three-way valve, (M) manometer, and (R) rotameter (see text for full explanation of legend).

ered by the normal truck battery, can be operated continuously for over 25 h. The maximum possible vacuum in a volume of 10 l. is 250 mm Hg. This makes it possible to extract samples from a height of up to 8.5 m above water surface. This performance is far superior to that normally required in the type of work for which the equipment is designed.

Sample collector

The system used to hold the intake tubes in place consists of a cylindrical expanded-polyethylene float 300 mm in diameter and 60 mm in height, through which passes axially an aluminium bar of suitable length (Fig. 1b). The bar is weighted to keep it upright and is fixed to the float by means of two clamps placed at the height required for the depth at which sampling is to be done. At each of the depths at which samples are to be taken an intake tube mouth is set. At each mouth it is possible to fix an angled nozzle of copper, glass or any other relatively inert material. The polyethylene tubes are held to the aluminium bar by plastic clips of the type normally used to hold electrical cables.

The intake tubes are polyethylene of 4 mm i.d. and 6 mm o.d. The length of the tubes obviously depends on the distance from the sampling location at which the sampling unit is to be set. The tubes run to the sampling unit partially submerged so as to prevent their heating through direct exposure to sunlight.

If it is wished to undertake sampling in the same place over a long period of time, the float can be anchored to the bottom or held by lines running to nearby stable positions.

Sampling unit

The various elements which compose the sampling unit are arranged inside a metal box from which emerge, on the left a tube connected to the vacuum system and, on the right, six inlets to which are connected the intake tubes for samples taken at the different levels selected (Fig. 2). The back and bottom of the box is lined with waterproofed wood where the various elements of the equipment are held or supported. Flasks G and L, and all the valves, are secured by partial embedding in the wood.

When valve R is opened, a vacuum is established directly in flask G. The three-way valve A allows flask G to be connected with the sample holder (which is attached to rubber stopper P) and with washing-flask L, or else it may open either of the two parts into which it divides the equipment to the atmosphere. To attach sample-holders or remove then when full, this part of the system must be opened to the atmosphere.

The depth from which a sample is to be taken is selected by means of multiple valve C. With three-way valve B, the sample can be sent either to the washing-flask or to the sample-holder. The samples flow directly on to the bottom of the latter through a glass tube with a plastic articulation, designed to facilitate input and extraction. Valve B has a third position by means of which water from a previous sample, contained in the tube connecting the sample-collection flask with valve B itself, can be directed to washing-flask L.

The purpose of flask L is to collect the water from the washing of the intake tubes before the sample is taken. This flask is emptied through side outlet F.

situated near the bottom. A drain-tube is connected to this outlet and is kept closed by a spring clip.

Stopper T on flask G is to run off any water which might accidentally enter through the vacuum line, without it being necessary to dismantle the equipment.

SAMPLING FOR THE MEASUREMENT OF DISSOLVED GASES

Although samples may be taken very rapidly, depending on the vacuum equipment used, when dissolved gas content is to be measured, it is inadvisable to work at excessively low pressures as degasification may occur in the samples.

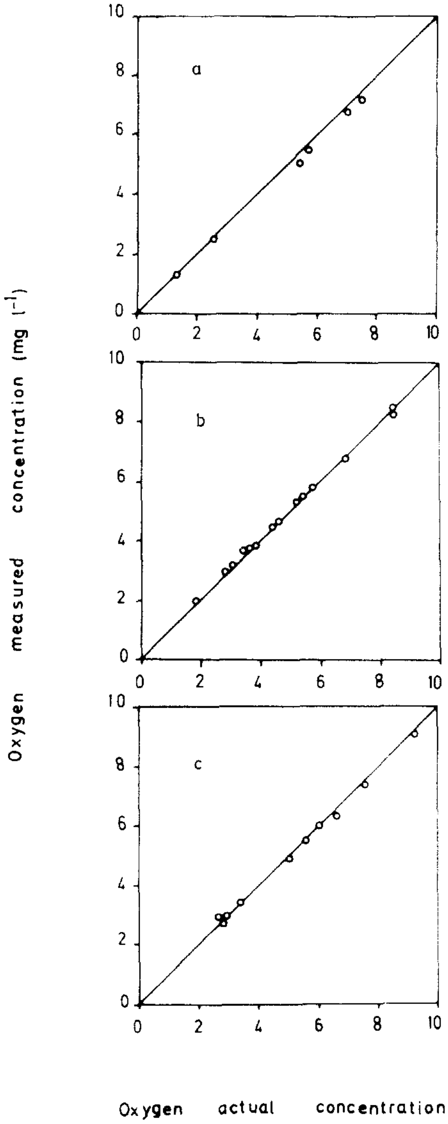

Fig. 4. Deviation of values of dissolved oxygen content in samples taken with the equipment, for three different working conditions: a—flowrate of 40 l h^{-1} and height of equipment above water sampled, 0.5 m; b—10.4 l h^{-1} and 0.5 m; c—10.4 l h^{-1} and 2 m.

In order to test alteration of the dissolved oxygen content of the samples caused by the reduced internal pressure of the equipment, the device shown in Fig. 3 was used. The samples were drawn from a tank of about 30 l. where oxygen concentration could be modified by bubbling air or nitrogen through diffuser D. A few minutes after the gas was cut off, one sample was drawn with the equipment and another was taken from a tap situated in the same area, in order to determine the oxygen content. All determinations were made using the Winkler method (Strickland and Parsons, 1972). The differences found are shown in Fig. 4 for three different working conditions: (i) sampling velocity 40 l h^{-1} and height (h) to which drawn, 0.5 m; (ii) 10.4 l h^{-1} and 0.5 m; (iii) 10.4 l h^{-1} and 2 m. The pressure inside the equipment can be calculated by means of Fig. 5, which corresponds to the vacuum equipment described previously.

Generally speaking, there is oxygen loss in the samples taken using the equipment described, as can be deduced from the points below the line of unit slope. The amount of loss is in direct proportion to the concentration of dissolved oxygen. The degasification is also greater when the pressure inside the equipment is lower.

In the two cases where the suction flowrate was 10.4 l h^{-1} the linear correlation coefficient between the values of oxygen determined in either way was very high (0.999) and their slope were close to unit-value (0.97 and 0.96). In these circumstances, the mean relative error over the whole range of oxygen concentrations tried is $<3\%$. These data are shown in Table 1.

In these cases the ordinates at origin show positive values, if not very significant ones (around 0.03 mg O_2 l^{-1}). This fact may be due to the greater amount of handling received by the samples obtained through the equipment, or else to turbulence in some valves or connections, whose effect would be more appreciable in samples of lesser oxygen content. This

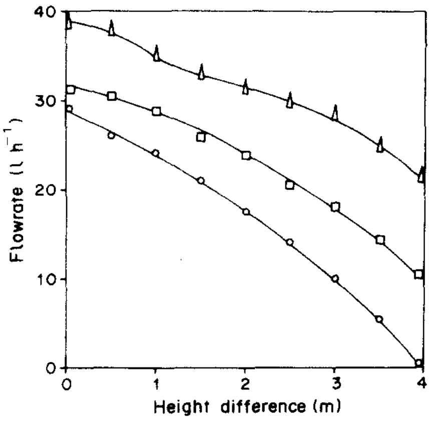

Fig. 5. Suction flowrate vs difference in height between equipment and surface of water sampled.

Table 1. Mean relative errors in values of dissolved oxygen content in samples taken using this equipment

Height difference (m)	Flowrate ($l\ h^{-1}$)	Correlation coefficient	Slope	Ordinate at origin (mg $O_2\ l^{-1}$)	Mean relative error (%)
0.5	40.0	0.997	0.94	0.03	5.4
0.5	10.4	0.999	0.97	0.12	3.0
2.0	10.4	0.999	0.96	0.07	2.6

phenomena can be produced also when the samples run in the intake tubes in laminar flow (Reynold's No. $\sim$1300). However, in field studies where this equipment has been used, oxygen concentrations of 0.00 mg l^{-1} have been obtained in those samples which came from oxygen-free sites.

ALTERATION OF SAMPLE TEMPERATURE

One disadvantage of sampling systems like the one described here is that the intake tubes pass through points whose temperature may be different from that of the sampling site. These temperature differences are normally slight when the tubes are submerged to prevent exposure to direct sunlight, or when the depth-range studied is small.

In order to determinate the error produced in sample temperature measurements by the effect of different temperature of the tubes, the device shown in the Fig. 6 was used. The samples were drawn from a thermostatic bath at temperature t_r, run through about 14 m of tubing submerged in another bath at temperature t_s, and was then collected through the equipment. Temperature was controlled by means of two previously calibrated Chrome-Alumel thermocouplings connected in series. One of the thermocouplings was placed in the bath from which the samples were taken and the other was inserted in the suction tubing close to the inlet in the sample-taking equipment.

Figure 7 shows the difference in temperature between the original samples t_r and those obtained through the equipment t_m against the sample volume drawn, for three different working conditions: (i) differences in temperature between samples and tubing of 1°C, (ii) differences of 2°C, and (iii) differences of 3°C. In all the cases the suction flowrate was 10.4 $l\ h^{-1}$. In each graph, where these working conditions are kept stable, three recordings are superimposed, corresponding to experiments in which the temperatures of samples and tubing were varied. The characteristics of these tests are shown in Table 2.

It will be observed that the curves stabilize once about 900 ml of sample has passed through the system, for which reason it is advised that such a volume of sample be pumped to the washing-flask before taking the aliquots to be used for measuring temperature.

The errors occurring in the measurement of sample temperatures grow along with the differences in temperature between the tubes and the specific sampling site. The length of the tubing obviously has its effect also. Operating in the conditions described above, and for temperature differences of around 1°C, the absolute error incurred is <0.1°C. Such a value may be considered acceptable as it should not be any

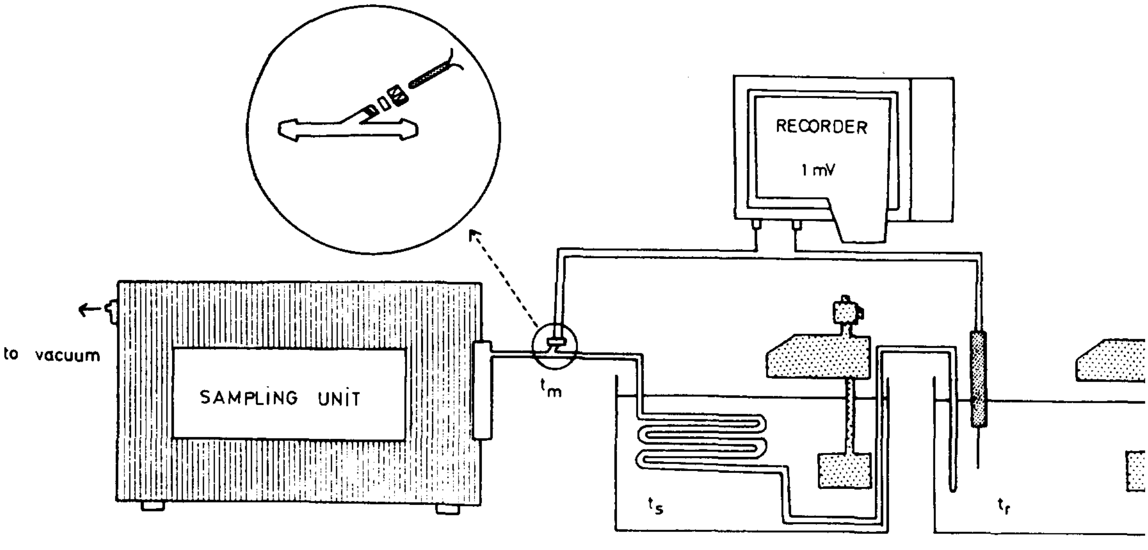

Fig. 6. Device for measuring temperature alteration in samples taken using this sampler (see text for legend).

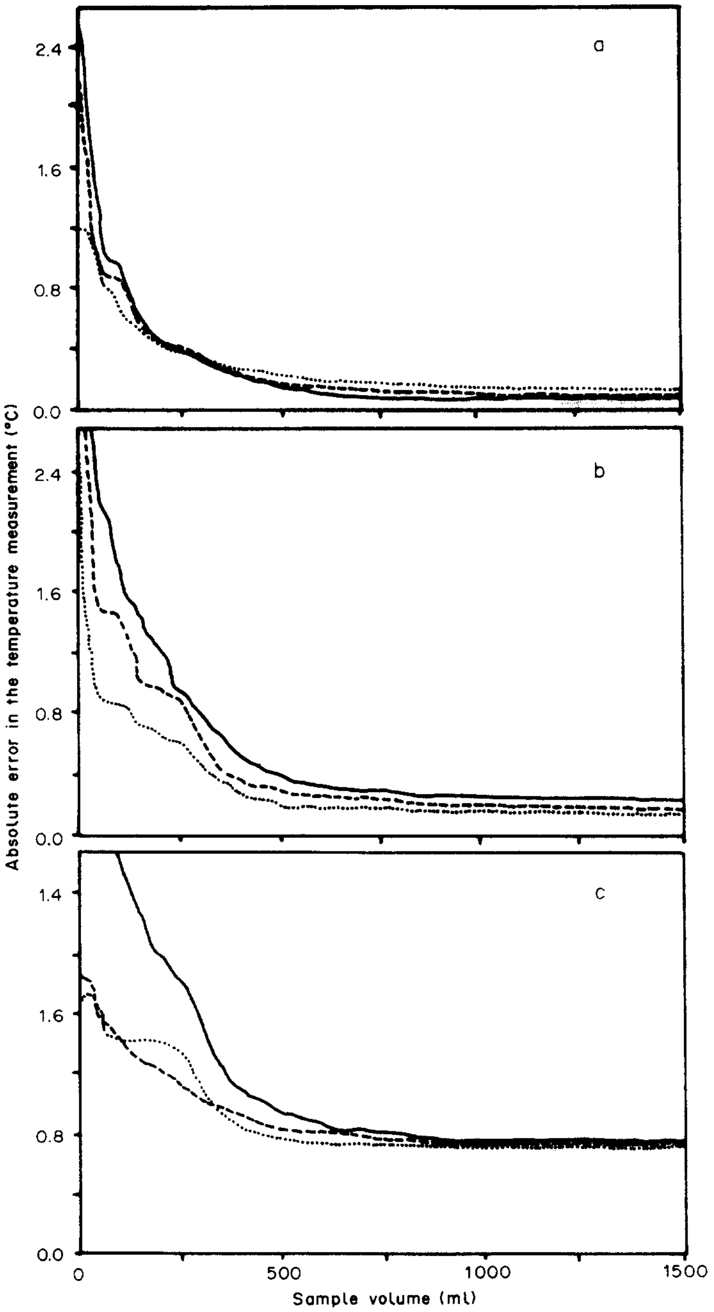

Fig. 7. Temperature alteration in samples vs volume of sample drawn, for differences the temperature between samples and tubes of: a—1°C; b—2°C; c—3°C.

Table 2. Errors in temperature measurements in samples taken using this equipment

Experiment	Temperature differences (°C)	Temperature of samples (°C)	Temperature of tubing (°C)	Mean relative error (%)	Absolute error (°C)
a	1	16 17 18	17 18 19	0.5	0.09
b	2	16 17 18	18 19 20	1.2	0.22
c	3	16 17 18	19 20 21	4.1	0.70

greater than that incurred in other commonly-used sampling systems.

FINAL CONSIDERATIONS

The equipment has given excellent results in sample-collection for determining nutrients, pH, alkalinity, salinity, solids in suspension and other parameters of physical and chemical interest in certain littoral ecosystems near the Bay of Cádiz, S.W. Spain (Forja *et al.*, in preparation). Measurements of temperature and dissolved gas content should be undertaken with the precautions described in this paper. This equipment is specially recommended as compared with traditional methods, for the taking of samples for the analysis of metallic traces (Segar and Berberian, 1975) as in this way the samples only come into contact with non-metallic materials (glass and polyethylene).

The time required for each sample using this device logically depends on the volume of the sample to be taken, which in turn depends on the number of parameters to be analysed. Another important consideration is whether or not samples are taken for the determination of dissolved gases. As a guide, the time needed to take 1500 ml samples at six different depths can be estimated at about 45 min. This time includes that required for the sluicing of each of the six intake tubes with 900 ml of water, sample-collection at a reduced flowrate for measuring dissolved oxygen, and the time spent in changing flask to store separately three aliquots of each of the samples.

On the other hand, this equipment is capable of improvements and modifications in order to increase its lendings. One of them would be the incorporation of a device to allow easier measuring and regulation of the pressure inside equipment for facilitating sample-taking for the determination of dissolved gases. It would also be interesting to install a continous filtration unit to allow sample-collection to determine quantitatively phytoplankton and solids in suspension.

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