Design, assembly and use of a simple, economical water sampler for suspended sediment collection

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Abstract. The behaviour of river can be perceived by analysing the sediments to a substantial extent. Computation of sediment weight per unit volume of water, sediment distribution along the quantifiable parameters of water body and mensuration of amount of useful as well as detrimental contents of sediments entails for sediment water sampling. The design and outline of an effortless and uncomplicated water sampler is presented in this paper. Although a number of manual, semi-automatic and fully automatic samplers are in attendance, there is a gap in asking price of previously available samplers and the present tool. The cost of sampler can be limited by designing for its specific purpose. The present sampler can only be used for top layers of water body (< 5 feet). But the same sampler can be modified for collection up to 10 to 15 feet. Design stresses of materials and force acting on the sampler is used to examine the safety of components used at the critical points. Manual design calculations and experimental use of the instrument in Kerian River, Malaysia evinces the approval of the design. The trouble-free design and facile use of the device will assist in suspended water monitoring for research in an economical way.

1. Introduction

The study of sediment has now become a mandatory part of water research. Sediments are either suspended in a water body or deposited on the bed. The instruments for sediments deposited as bed load are bulky and different in operation from water samplers used for suspended sediments [1]. Numerous costly and complex water samplers can be found on internet search. Sometimes a difficult operation leads to errors in sampling [2]. The devices designed till date have various manufacturing approaches, mechanism, materials, and cost. Some sampling devices are produced using 3D printing [3] while others are designed using syringes, microcontrollers and solenoid valve enclosed in a casing [4]. The materials used in a sampler are selected according to the requirement. Generally the material needs to be non-reactive, non-corrosive and should remain unaffected by salts and sulphides. Researchers have also carried out evaluation of such sampling devices for metal specifications on water treatment plants and in urban runoff water [5]. Passive samplers are used for analysis of antibiotics [6, 7] and organic contaminants [8]. Sensors are also incorporated in automatic sampling system for applications in agricultural field [9]. Similarly, ultrasound sensors and microcontrollers were utilized along with hydraulic equipment’s in other samplers [10]. Automated samplers are also useful for probing marine biodiversity [11]. Drones and solenoid valves are used in compact and fully automatic samplers as well [12, 13]. For arctic environments, these sampler carrying Unmanned Aerial
Vehicles (UAV’s) or drones prove out very helpful in sample collection [14]. The suspended sediments also carry large amount of chemical constituents. The chemical gradients present in water-sediment interface can be studied by collecting the water sample using bottom samplers fitted in a boat [15]. Large volume samplers are also assembled that can be used for remote locations as well as deep water bodies [16]. In the same perspective, large volume samplers having pores are suitable for sandy and muddy layer substrates [17]. For small streams and drips having discharge in between 0.5 to 200 mL/min, composite water samplers are perfect for use [18]. Thus, countless samplers are designed according to the working scenario and requirements.

Apart from objective based samplers, standard instruments are also available in the market sold by various manufactures. Bottle and trap samplers such as USP-61 point integrating sampler, Delft bottle sampler, USD-49 depth integrating sampler and collapsible bag samplers are readily available but at a higher cost. Pump samplers equipped with either filter or bottle forms bulky and heavy in size. Optical and Acoustical sensors can measure the turbidity of water without collecting the water sample for further investigation [1]. The price of preceding samplers are between $20 [17] to $500 [2].

Thus from the literature survey it is deduced that every single purpose, samplers can be designed depending on the requirement and expenses. The objective of the present work is to design a sampler for water collection from surface and near surface layers. Also, a quick design using material stresses is aimed with a stringent focus on the cost incurred in the components used in the apparatus.

2. Design of instrument

Figure 1 shows the design steps considered in the assembly of instrument. Standard design procedures are followed wherein selection of materials, analysis of forces, design and safety check is carried out [19]. The description and cost of the components used in the sampler is tabulated in Table 1. Slotted angle bar as a main body, syringe for water collection, rope for pulling of syringe and cable tie for holding syringe and other miscellaneous work are used in the design. The overall cost of instrument is limited to $10 only. Final assembled instrument is shown in Figure 2 while components used are shown in Figure 3, Figure 4 and Figure 5. The slotted angle bar and syringe is visible in the Figure 2 with complete assembly, holes in plunger of syringe for strong grip between rope and plunger in Figure 3, rope setup in Figure 4 and cable ties in Figure 5 can be seen. Twin rope setup is used for ensuring better grip and smooth suction movement.

![Figure 1. Steps involved in design of water sampler](image-url)
Table 1. List of components installed

| Sr. No. | Description of Components                           | Material            | Quantity | Price ($)|
|---------|------------------------------------------------------|---------------------|----------|----------|
| 1.      | Slotted angle bar (5’×2\(\frac{1}{4}\)’×1\(\frac{1}{2}\)”) | Mild Steel (M.S.)   | 1        | 6        |
| 2.      | Syringe (200 mL)                                      | Polypropylene       | 1        | 1.50     |
| 3.      | Nylon Rope (2 mm diameter, 30 m length)               | Nylon               | 1        | 2        |
| 4.      | Cable tie (300 mm × 4 mm, 30 pieces)                  | Nylon Grade-66      | 1 Pack   | 0.50     |
|         | **Total**                                             |                     |          | **$10**  |

Figure 2. Final assembled water sampler

Figure 3. Holes soldered in syringe for passage of nylon rope
From design point of view, two forces are acting on the sampler. First, the force acting on the sampler due to flowing water and second, the force applied by operator on rope for collection of sample. The force acting due to flowing water on sampler is calculated using Equation 1, Equation 2 and Equation 3 [20]. Where, $F_D$ is drag force, $F_L$ is lift force, $F_R$ is resultant force. $C_D$ is coefficient of drag, $C_L$ is coefficient of lift, $A$ is area perpendicular to the flow, $\rho$ is density of water and $U$ is velocity of water. The resultant force acting on the sampler due to flowing water is equivalent to 370 N. The force acting on the rope due to pulling action by the operator is assumed to be 20 N taking into consideration the smooth action of plunger. The stresses occurring due to these two forces on the critical section of the sampler and safety check of sampler by its comparison with design stresses of materials is shown in Table 2.
Table 2. Safety check of water sampler

| Sr. No. | Nature and Location of Stress          | Corresponding stress (N/mm²) | Permissible stress (N/mm²) | Safe or Unsafe |
|---------|----------------------------------------|------------------------------|---------------------------|----------------|
| 1.      | Bending stress on angle bar due to water | 182.07                      | 360                       | Safe           |
| 2.      | Tension in Nylon rope due to pull       | 6.36                        | 82.7                      | Safe           |
| 3.      | Shear in syringe due to nylon rope      | 0.167                       | 40                        | Safe           |

3. Modus operandi
The syringe is attached to the slotted angle bar at one end with the help of 4 tightened cable ties (Figure 6). One cable tie is used on plunger side to limit the sliding movement of cylinder of syringe. Thus holding the syringe in a fixed position. On pulling the rope, the plunger moves and enables the suction of water sample (Figure 7). Another cable tie is located at maximum position of plunger so as to collect exact 200 mL of sample (Figure 7). The entrance of syringe nozzle is 3.25 mm in diameter having enough size for suspended sediment particle [21].
4. Discussion on trial of instrument

For trial of instrument, a field visit was conducted on Kerian River, in the northern Malaysian state of Penang. The trial of sampler was successfully conducted on 14th July, 2020. A motor boat was used for travelling to the downstream of Kerian River. Figure 8 and Figure 9 shows the manual operation of the sampler. The stiffness of the sampler was perfect for bearing the force applied by the flowing water. The slots help in smooth passage of flowing water thereby exerting less force on the sampler. The sample water collected was stored in specimen containers as shown in Figure 10. The water samples will be used for further analysis of sediments.

![Figure 8. Water sampler inserted in Kerian River, Malaysia for sample collection](image1)

![Figure 9. Water sample extracted using the device](image2)

![Figure 10. Manual extraction of water from sampler to specimen containers](image3)

Figure 11 shows the water extracted in mL from Kerian River at 12 study points. Although the instrument is totally manual, the quantity of water fetched deviates to very small amount. The water sample collected was 200 mL equivalent to the cylinder capacity. The precision of instrument is visible in the trend line of the plot. The standard deviation of the water sample is 4.814. Similar design can be used for various syringe capacity and angle bar length. Further modification will be carried out in the sampler by addition of a servomotor and Arduino for semi-automation in further study. The addition of Arduino will help to make suction operation automated. Also, power to the Arduino and
motor can be supplied using a laptop. Moreover, supplement of a conventional spring mechanism will make the sampler fully-automatic where suction and extraction of water can be automated. Also, the slots in the angle bar can be used to attach the sampler to the hull of boat so as to use it as a base sampler. Inclusion of one to two slotted angle bar can be done so as to collect sample up to a depth of 10 to 15 feet. Thus, the scope of enhancement in the water sampler is vast which further can be integrated with heavy metal potentiostat [22].

![Graph](image)

**Figure 11.** Trend of quantity of water sample collected using the sampler

5. Conclusions
The objective of low cost and quick design of water sampler is achieved in the study. The purpose of suspended sediment collection is demonstrated by the trial of sampler on the Kerian River. The cost of the sampler was restricted to $10 along with limiting the total weight of the sampler to 1.260 kg. The cost and weight of the sampler is lowest among all the previous samplers mention in the literature survey. The selection of materials, force analysis, safety check is achieved in an out-right manner. The portability and light weight of the sampler supports the research on suspended sediments in perfect way.

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