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Affordable onsite *E. coli* testing device for community engagement

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Abstract. The need for affordable onsite sensing device (AOSD) has been determined in the medical, environmental, and educational fields since mid 2000s. This article aims to explore the unique nature and definition of the AOSD, and conclusively culminated the discussion into a designed prototype trial device. The definition of AOSD was concluded as "a unique cost efficient device that can solve users' actual small problems giving unique experimental capacity to improve their quality of life, quality of education, quality of environment, and quality of job under quite resource limited settings". The best water hygiene indicator, *E. coli*, was selected as an example of analyte. A designed prototype trial *E. coli* AOSD showed very good performance in a community engagement program in LAO PDR.

Introduction

Since the mid 2000s, there has been an increasing need for new capacity for` affordable onsite sensing devices (AOSD) in the medical field [1] and water environmental management [2], which is also useful in experiential learning [3]. There isn't comprehensive definition for AOSD yet over such wide disciplines. Though the WHO's definition would be helpful: i) Affordable, ii) Sensitive, iii) Specific, iv) User-friendly, v) Rapid and robust, vi) Equipment-free, and vii) Delivered to those who need it [1]. AOSD is an ongoing innovation to bring new benefits to communities. However users often show reluctance to use it due to conservative bureaucratic thought with proactive techniques by high-tech instruments and corresponding human skills [2]. Hence, the clear definition of AOSD with character of testing location has high impact to global humanity and environmental conservation due to the wide spectrum of potential users. This article aims to carry out the definition and unique nature of AOSD, and to conclude all the discussion into a prototype trial AOSD.

In the drinking water management framework, the main concerns are to develop the capacity to supply microbially safe water, and to discourage less microbially safe water consumption [4]. *E. coli* contamination testing is recommended for the minimum monitoring parameter in water-supplies as *E. coli* is the best indicator for fecal contamination i.e. risk of the hygienic state of drinking water [4]. Hence, *E. coli* testing AOSD was selected to design potential prototype product of AOSD.

Platform technique. Bacteria contamination test strip is one of the simplest devices to convert traditional chromogenic enzyme assay into mobile phase. Coliform bacteria and *E. coli* simultaneous test strip (product of Sun Chemical, Japan) is good example of such [5,6]. Pith of the chromogenic

enzyme assay mobilization technology is novel utilization of certain size of filter paper (20x125mm) and casing zip-lock plastic bag (Fig. 1). The size of the test strip is adjusted to hold 1 mL sample inside, and the test strip represent culture plate to keep cultivation medium and sensing molecules. Moreover, the casing plastic bag functions as preserver of the sterilized bacterial test strip before the experiment, it serves the role of a container to incubate sample held in the test strip, and functions as barrier between incubated sample and experimenter. The result of assay can be inspected through the transparent casing plastic bag without opening it. Finally, the casing plastic bag functions as a container to dispose microbiological experimental waste as burnable waste. The bacterial test strip has 1 cfu (colony forming unit)/mL level sensitivity, and a test tube costs around < 1.5 USD.

Methodology

A list to compare typical difference of laboratory characters between resource rich and resource limited setting was made (Table 1) by modification of a similar prior table [1]. A prototype trial AOSD is designed by the resulted definition of the AOSD. Application fieldwork was performed at Ban Na Gnom Mai (a village), LAO PDR on 21st March, 2014. The fieldwork was a part of a community engagement program. The trained personnel were only three, and the given time frame for the fieldwork was just 1.5 hour. Four households (No.1 to No.4) were selected from marginal to central part of the village and valid field work was performed by two groups.

Results and Discussion

The definition of AOSD. The capability of different level of laboratories was listed taking into context with different resource availabilities and unique demand for outcome data handling (Table 1). The comprehensive trend indicated an inverse proportion between resource setting and actual rapid advice requirement. By this trend, the priority demand to the AOSD was simply concluded as low cost and rapid answer. With assuming users, the definition for AOSD was "a unique cost efficient device that can solve users' actual small problems giving unique experimental capacity to improve their quality of life, quality of education, quality of environment, and quality of job under quite resource limited settings".

Table 1. Category of laboratory and resource settings.

Category of laboratory	Resource settings	Infra-structure	Trained personnel	Laboratory space	Outcome data/ information handling
Moderate to advanced	Rich	Dependable	Dedicated	Good	Time to answer usually less crucial for visitors, but still Important to enhance research cycle.
Minimal	Limited	Minimal		Minimal/ temporal	Required to prescribe/recommend conclusion before patient/ participants/ student leaves
Exlaboratory	Quite limited	Rarely			Advice expected but it is just prediction from phenomenal consideration without local data
AOSD					Required to prescribe/recommend conclusion before patient/ participants/ student leaves

Infrastructure: Equipment, clean water, electricity, cold storage, etc.; exlaboratory: out of these laboratory service setting; assumed users were in medical, environment, and educational field.

Prototype trial AOSD. Simply put, the demand for AOSD arises as a result of resource limited setting (Table 1), accordingly, AOSD must independently function without any laboratory logistics as total analytical system. Herewith, we noticed bacterial test strip [5-6] is only easy-to-use detector (Fig. 1a). It can be improved as an affordable comprehensive analytical device if low-cost incubator (10 USD level) can be prepared by locally available material without special skill. Subsequently, an affordable incubator was made (Fig. 1b) and *E. coli* AOSD could be designed as a total analytical device. Valid triplicated 20 points field investigation (11:00AM-12:30/21/Sep) was easily performed by two groups. After 18 hours incubation over night, total coliform and *E. coli* were counted

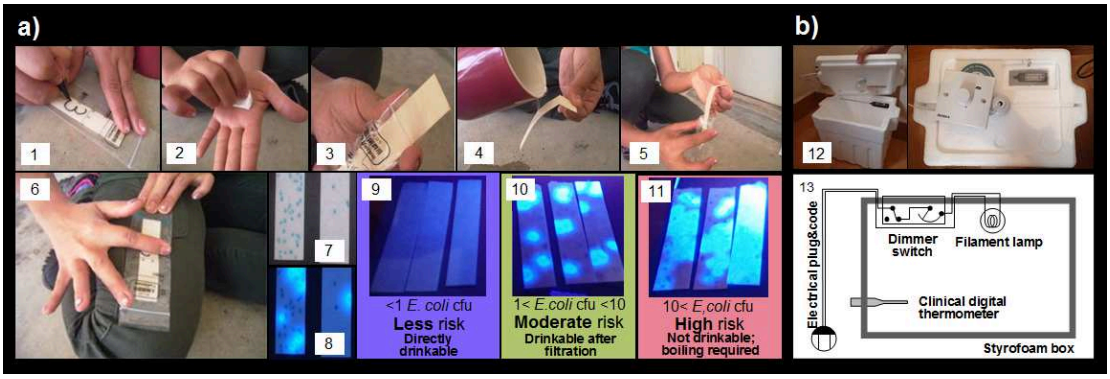

Fig. 1. An example of *E. coli* AOSD. a) The coliform bacteria and *E. coli* testing. 1: labelling sample ID, 2: hand sterilization by alcohol, 3: unsealing zip-lock, 4: sample dosing from one side (1 mL sample capacity), 5: inserting the test strip and tearing off handle, 6: discharging air from the bag and zipping, 7: formation of dark blue spots (coliform bacteria), and 8: view of blue spot (*E. coli*) under UV light at 360nm (after incubation for 20 hours at 36 ^{o}C), 9-11: risk criteria for water hygiene by *E. coli* contamination level [5-7]. b) 12: low cost incubator, and 13: schematics of the structure.

	Well water	Water in tank	Filtered water
E. Coli [cfu/mL]			
Well No.1	0	0	0
Well No.2	6.0	5.0	0.7
Well No.3	17.3	-	1.0
Well No.4	20.7	-	2.3
Total coliforms [cfu/mL]			
Well No.1	3.7	5.7	0
Well No.2	26.7	23.3	3.3
Well No.3	53.0	-	6.7
Well No.4	109.3	-	41.3

cfu: colony forming unit, -: not measured .

Fig. 2. Fieldwork and results of the conducted study using *E. coli* AOSD.

(6:00AM-7:30/22/Sep). The results of the participatory field investigation were presented with supportive information and story to villagers at community centre (Fig. 3, 10:00AM-12:00/22/Sep). The *E. coli* contamination was zero at marginal part of the village and gradually changed to serious level around the central zone (20 cfu/mL < *E. coli*). Drinking water is processed by bio-sand filtration at many households in the village. The results showed the efficiency of the filtration was 91% *E. coli* removal ($y = 0.09x$, $R^2 = 0.81$). Due to the relationship, treatable water resource was assessed as *E.*

coli < 11 cfu/mL. In the village, the feasibility of bio-sand filtration at marginal zone, and its limitation due to serious groundwater pollution around the central zone of the village were found, respectively. In the community engagement program, the critical point was to share the end of problem solving in mind from multi-individual sense via "what do I want to do". Thereupon, as the result shown was quite visible (Fig. 2), it was simple for the villagers to understand the results. The trial *E.coli* AOSD effectively could provide the real information for their daily water hygiene (Fig. 3). Subsequently happened naturally activated discussions, regarding potential solutions with available local techniques, were the proof of unique role of trial *E. coli* AOSD. Such capacity is considered as crucial in waterworks undeveloped laboratory resource poor areas, e.g. the most area of Lao PDR.

Fig. 3. The presentation during fieldwork.

Summary

The definition of AOSD was "unique experimental capacity by cost efficient device that can solve each of users' actual small problems to improve their quality of life, quality of education, quality of environment, and quality of job under their quite resource limited settings". Designed prototype trial *E. coli* AOSD was consisted of handling-manual, water criteria to interpret results, alcohol in vials, *E. coli* test strip, low cost incubator, UV lamp, and aluminium foil. The device showed very good performance in a community engagement program for water hygiene in LAO PDR.

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