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Effect of turbidity on survival of Escherichia coli, feacal coliform and total coliform in grey water by using solar disinfection (SODIS)

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Abstract. Tropical country like India can use an alternative disinfection option to utilize solar energy for disinfecting grey before reuse. This study was aimed to conduct experiments to examine the impact of turbidity (75NTU, 50NTU and 30 NTU). This experiments were carried to inactivate EC (Escherichia Coli), FC (Feacal Coliform) and TC (Total Coliform) at different flow-rate (33.4, 44.3, 66.8, 135, 268 and 555 ml/min) by solar radiation intensity. It was observed that as turbidity and flow-rate as goes on decreasing inactivation of bacteria goes on increasing.

Keywords. Escherichia Coli, Grey water, Solar Disinfection, SODIS, Turbidity

1. Introduction

Clean and safe drinking water is foremost importance for good human health. Approximately, 783 million people of the world population (11%) is deprived of improved drinking water source and nearly 605 million people still lack coverage. By the year 2025 India will face water scarcity. The main reasons behind this global issue of water scarcity are climatology, demographic pressure and rapid population growth [1][2][3]. This challenge of water scarcity can be overcome by water demand management system [4]. Grey water reuse is increasingly emerging as an integral part of water demand management [3]. This can be achieved by eco-friendly low cost technology. Grey water is must be used for other purposes except drinking [5] which substantially reduces potable water consumption by about 30 % [6] for other activities such as cleaning, flushing and gardening except drinking. If these uses are to be materialized then disinfection of grey water will be essentially required to eliminate the pathogenic microbial contamination present in the grey water [7].

1.1. Potential of Solar Radiation to Disinfect Grey Water

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Use of chemical disinfection (Chlorine) gives rise to disinfection by-products which showed health impact [8]. Use of advanced technologies such as ozonation and UV radiation are not desirable since it may not be economically viable for disinfection of grey water. In view of these especially in developing countries a low cost, low maintenance disinfection system is being looked up to for disinfection. Solar disinfection is found to be more economic and environment friendly option which can be easily utilized for disinfective removal of *Escherichia coli, Shigella flexneri, Salmonella Typhimurium* and *Vibrio cholerae* [10]. Similarly microorganisms found in grey water can also be removed if SODIS is used for disinfecting grey water. Few researchers have expressed limitation of using solar disinfection especially for the grey water which is turbid in nature [11].

1.2. Effect of Turbidity on inactivation of pathogenic micro-organisms

SODIS takes advantage of solar energy which is abundantly present in many developing countries [12] [13]. The SODIS Manual recommended that for disinfection of untreated raw water, it should be exposed to at least for 6 hours to direct sunlight or 2 consecutive days in case there of 50% cloudy day. Raw water turbidity should not exceed 30 NTU [13] [14] [15]. The proven technology of SODIS is synergistic effect (UV-A radiation) and heat which is be effective under both natural and simulated laboratory conditions [13] [16] [17] [18]. At higher turbidity levels SODIS can work [16] its effectiveness decreases if turbidity is more than 30 NTU [14]. It was reported that higher the turbidity lower will be the inactivation efficiency of SODIS [12] [13]. Turbidity is caused by suspended material such as small particles, fecal matter, or colloids present in the contaminated water which help to shield microorganisms from irradiation [19][20][21]. Form few research study it revealed at higher turbid levels microbiological inactivation decreases as synergistic effect is not occurred in the water samples [12].

Turbidity affects the performance of the solar collector. At moderate solar intensity exposure time is also prolonged [22]. At moderate turbidity (38 NTU) did not reduce the inactivation efficiency, but slightly enhanced it [23]. After 8 hours to strong sunshine with turbidity 300 NTU bacterial inactivation was achievable [12]. When contaminated water *by E.coli* was exposed to strong sunshine so that water temperature rises to 55° C within 7 hours, completely disinfection was achieved [17] [24].In Massai, contaminated water with turbidity of 200 NTU which causes risk of diarrhoeal diseases in children was reduced when exposed to strong sunlight [25]. Solar collector disinfection efficiency decreased up to 15%, due to high turbidity levels [26] to increase efficiency turbidity levels should be decreased by filtering [11]. It was observed that with low turbidity levels better results were observed [26].

Therefore, this research work was aimed to assess efficiency of the developed solar collector for the inactivation of EC (*Escherichia Coli*), FC (Feacal Coliform) and TC (Total Coliform) at three turbidity levels 75, 50 and 30 NTU at the different flow rates. So, that to decide the maximum extent of initial turbidity that will be acceptable for SODIS collector.

2. Methodology

2.1. Collection of Sample

Influent samples of grey water were collected from residential building. Turbidimeter (Lamatte 2020e, USA) was used to measure turbidity. Experiments were carried out at 75, 50 and 30 NTU at the different flow rates and at base angle 45° inclined tubes of SODIS treatment unit. Constant flow rate of 33.4, 44.3, 66.8, 135, 268 and 555 ml/min was maintained by peristaltic pump (HBS Technologies, ENERTECH) for the each set of experimentation.

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2.2. Structure of Solar Collector

Rectangular solar collector with radius 25.25 cm. This collector was made up of steel body (70.5 cm X 45 cm with a height of 55.25 cm). In this semicircular collector five borosilicate tubes were placed equidistant (10 cm apart) and each having capacity 400 ml. This whole assembly was mounted on stand of size 70.5cm X 1000 cm [24]. For the purpose of insulation glass wool was filled in the space of rectangular solar collector.

2.3. Experimental procedure of solar collector

Experimentations were conducted on the solar collector made up of boro-silicate glass tubes with 4 litres of grey water (illuminated volume 2 litres + bottle reservoir at the bottom volume 2 litres). The experiments were conducted with the influent turbidity (75, 50 and 30 NTU) with reflective rear surface and at a base angle of 45^o. Influent turbidity was observed to be varying. Turbidity fed to solar collector was diluted to said turbidity. The solar collector was placed in such a way that it should get maximum sunlight radiation. The exposure period to solar radiation was 8 hours (9:00 AM to 5:00 PM, IST). Temperature was recorded for atmosphere, bottle reactor and reflective rear surface in °C. First reading at 9:00 am, second reading at 12:00 PM, third reading at 2:00 PM, fourth reading at 4:00 PM and fifth reading at 5:00PM were recorded for the each set of experiment (Not shown here). At the same time reading by First class Pyranometer (Make: Sivara Systems and Solutions) UV intensity was recorded. All experiments were performed with the solar intensity 670 to 700 W/m² noon time.

2.4 Microbial Study

In sterile glass bottle (250 ml) microbial tests samples for were collected within an hour and it was kept for analysis in the laboratory. Microbial experiments were performed in sterile condition. Most Probable Number (MPN) method was adapted for microbial study to determine EC, FC and TC as per Standard Methods for the Examination of Water and Wastewater (1999) [27].

3. Results and Discussion

It was observed similar pattern of temperature gain occurred during the different levels of turbidity at maximum solar intensity at noon. Maximum value of solar radiation was observed at afternoon. The stronger the sunlight radiation, the higher is the water temperature and it drops as solar radiation decreasing [26]. Depending upon the weather conditions (moderate to strong) maximum temperature difference between the bottle reservoir and atmosphere was observed at 5-7° C with varying levels of turbidity. Applying a reflective rear surface facilitated the temperature gain which subsequently enhanced the efficiency of UV radiation for microbial inactivation. [9] [12] [22].

The influent grey water turbidity was found to be 82.19 ± 37.85 NTU. To find the appropriate turbidity for the solar collector to get maximum inactivation of EC, FC and TC studies on the different level of turbidity were performed at 75, 50 and 30 NTU. At 75 NTU, EC, FC and TC percentage inactivation varied minimum to maximum from 40.63 to 62.86, 55.56 to 72.86 and 61.96 to 78.13 respectively (Figure 3.1). When the same set of experimentation was performed with 50 NTU, at different flow rates with solar intensity variation from 470.6 to 584.0 W/m². Percentage inactivation was found to be varied from 60.7 to 73.3, 66.3 to 79.6, and 73.9 to 85.4 in EC, FC and TC respectively (Figure 3.2). At 30 NTU with solar intensity variation from 450.7 to 532.7 W/m², percentage inactivation in EC, FC and TC varied from 63.4 to 77.0, 76.1 to 97.1 and 78.1 to 97.5 respectively (Figure 3.3).

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Figure 3.1 Percentage Inactivation in EC, FC and TC at Constant Turbidity of 75 NTU at Varying Flowrate with Reflective Rear Surface



Figure 3.2 Percentage Inactivation in EC, FC and TC at Constant Turbidity of 50 NTU at Varying Flowrate with Reflective Rear Surface



Figure 3.3 Percentage Inactivation in EC, FC and TC at Constant Turbidity of 30 NTU at Varying Flowrate with Reflective Rear Surface

From the results it was observed that percentage inactivation increased with decrease in turbidity. Similar finding was reported by [13]. As turbidity was decreased from 75 to 30 NTU, percentage inactivation was improved by about 17 %, 25 % and 19% in EC, FC and TC respectively similar to finding of Amin et al., 2009. At higher turbidity levels suspended particles absorption UV [26]. No significant rise in temperature with 50 NTU turbidity [21]. It was observed that at less turbidity yield higher inactivation at moderate intensity similar to Gomez-Couso et al., 2009 [13]. Joyce et al. [17] reported inactivation with higher turbidity can be achieved when water temperature reached at least 55°C. Also according to [14]. It is observed from the study that the turbidity below 50 NTU provides lesser interference to solar disinfection. No significant rise in temperature with 50 NTU turbidity [21].SODIS is implementable till 30 NTU for water treatment at 3-5 h of solar radiation above 500W/m².

4. Conclusion

Developing countries like India are vulnerable to water scarcity which can be partially overcome by reuse of the grey water for other purposes except drinking. Disinfection of the grey water is imperative but the conventional disinfection methods used for water treatment are not suitably applied. The study indicated the feasibility of solar disinfection system for treatment of grey water for further reuse. Higher levels of turbidity were found to be detrimental to the efficiency of SODIS. Percentage inactivation of coliforms increased with decrease in turbidity. If turbidity is high at that time solar radiation required at least 500 W/m² for 6 hours.

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