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SANITATION AND WATER FOR ALL

Progress in solar water disinfection (SODIS)

Martin Wegelin, Rehan Ahmed and Noman Ahmed, Switzerland

MAJORITY OF THE 130 million population in Pakistan like in other developing countries has no access to safe and reliable drinking water supplies. The population is forced to use polluted surface waters from rivers, irrigation canals, ponds, lakes and ditches. This surface water is carrier of many infectious and tropical diseases and must be treated prior to consumption. The lack of adequate and potable water supply and sanitation facilities seriously exposes the already malnourished population to numerous water related diseases. A dominant disease due to contaminated drinking water is diarrhoea. Globally there are about 875 million cases of diarrhoea annually out of which 4.6 million result in death. The main target of any water treatment is the removal or inactivation of disease causing microorganisms like bacteria, viruses, protozoal cysts and worm eggs. Disinfection is usually applied by chlorination and slow sand filtration which are not available in rural areas due to lack of funds, skills and other resources. Hence a reliable, efficient, low cost and sustainable water treatment is much required especially for the domestic purposes.

Karachi with a population of around 15 million is like any other mega city where the provision of infrastructure does not cope with the growing population. This phenomenon has resulted in formation of over 532 slums and squatter settlements in Karachi where more than 40 per cent of the city's population reside. Though majority of the slums are connected to the piped water supply system, but the quality of water is not safe which is confirmed by various microbiological tests performed by different organisations and NGOs.

The concept of SODIS developed by EAWAG/SANDEC was tested in the slum locality in Karachi to assess its success, acceptability, applicability and affordability. The paper describes the methodology and concept of SODIS tested in other areas and results of the research carried out in Karachi with the assistance of SANDEC.

Solar water disinfection (SODIS)

SODIS stands for Solar Water Disinfection. The SODIS concept is to utilise the solar energy to produce small quantities of drinking water at household level. Solar energy is abundantly and universally available free of cost and can be conveniently utilised to provide a simple, efficient and sustainable water treatment option. The concept of the SODIS project was developed by Swiss Federal Institute for Environmental Science & Technology EAWAG/ Water & Sanitation in Developing Countries SANDEC. The SODIS project was initiated in 1991 and was extensively tested through laboratory and field experience to assess the potential of SODIS. The basic concept of the treatment process involves the use of transparent containers, which are filled with water and exposed to full sunlight for several hours. The process is found to be efficient in killing and inactivating the microorganisms by radiation. SODIS has been used as a batch process at household level to treat small quantities of drinking water in bottles and plastic bags. The three phases of the project are

Phase 1

Comprehensive laboratory and field tests to determine the potential and limitations of the disinfection process.

During Phase I, a project team comprising of sanitary engineers, photo- chemists, bacteriologists and virologists conducted the comprehensive laboratory tests at EAWAG on inactivation of bacteria (E. coli., Str. Faecalis, Enterococci), viruses (EMC virus, rotavirus) and bacteriophages.

The SODIS concept take the advantages of UV-A radiation and pasteurisation processes which compliment each other and compensate for the partly unfavourable climatic conditions. The combined effects and discovered synergies between solar radiation and temperature is mentioned in Figure 1. It illustrates the synergies produced by the combined use of radiation and thermal treatment on the inactivation of faecal coliforms. The results of two different faecal coliform inactivation tests carried out at constant water temperature at 30 °C and 50 °C is shown in the above mentioned figure. A series of parameter tests at water temperatures of 20 and 55 °C revealed that the inactivation rate of faecal coliforms remains constant within 20 and 40 °C temperature range. However at a threshold water temperature of 50 °C, the required fluence of UV-A light is four times smaller than at 30 °C and cause inactivation of bacteria due to heat effect, sunlight exposure and synergies caused by the combined application of temperature and radiation. The field tests confirmed that as soon as the water temperature reached 50 °C, the inactivation process is accelerated and it often leads to a complete disinfection of water.

Phase 2

Field tests to develop equipment and operating guidelines for the water treatment method.

SODIS requires sunlight, exposure time and adequate containers to produce drinking water. During Phase 2 different containers and reactors for water treatment process were tested in different countries including plastic and glass containers. The results revealed that UV-A transmis-

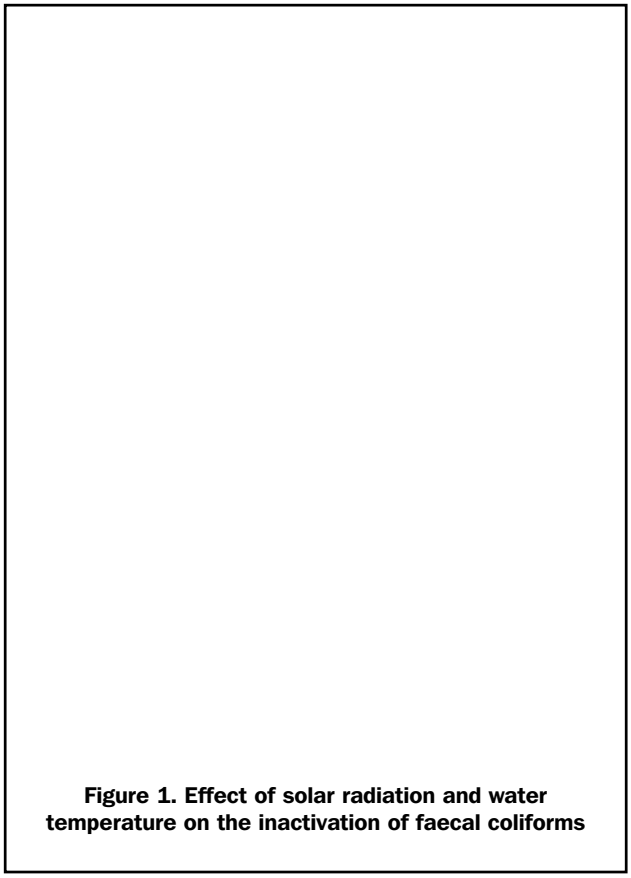

Figure 1. Effect of solar radiation and water temperature on the inactivation of faecal coliforms

sion losses are 30 per cent for plastic bottles, 25 per cent for glass bottles and 10 per cent for plastic bags.

In SODIS the PET (polyethylene terrephtalate) bottle was preferred than PVC bottles due to their availability, price and absence of any additives which could diffuse into the water and pose a health risk. PET bottles are inert and therefore was recommended for SODIS use by SANDEC.

To improve water heating, transparent plastic bottles are half blackened to enhance infrared light absorption. Furthermore the ratio between exposed surface area and stored water volume greatly influences temperature development. The experiments also yielded that the type and shape of support material used to carry the plastic bottles directly influence the water temperature development. Half blackened plastic bottles placed on a corrugated iron roof offer the best configuration for SODIS batch proceeds application.

The polluted water is bottled and exposed to sunlight which travel through the wall of the bottle into the water. UV-A light with a wavelength 320-400 nm is mainly responsible for the inactivation of micro organisms. Violet light (400-450nm) alone is hardly bactericidal. However due to synergetic effects with UV-A light, its inactivation rate on E. coli is increased by a factor of 3.

The die-off rate of faecal coliforms under different stress factors clearly illustrates the synergetic effect. Viruses including Rotavirus, Encephaloyocarditis virus and bacteriophage f2 are more temperature sensitive and their die-off rate steadily increases with temperature in the range of 20-50 °C. The inactivation of microorgansims by plastic bottles and bags is illustrated in Figure 2.

Phase 3

Demonstration projects to study socio-cultural acceptance and affordability of SODIS.

Phase 3 of the project is in progress in which socio-cultural acceptance, applicability and financial aspects of the water treatment methods are currently studied in demonstration projects conducted by local partners in Colombia, Bolivia, Burkina Faso, Togo, Indonesia, Thailand and China. The ongoing projects are expected to produce valuable information on the subject which can then be promoted and publicised on a large scale after thorough evaluation.

Sodis experiments in Karachi

Following are the methodology and results of the SODIS experiments conducted in Karachi:

- Testing for the Bottles: Plastic soft drinks bottles are commonly available in Karachi and are affordable to the low-income people as well. A clean empty plastic bottle of 1.5 litres cost Rs 1.0 and 2 litres costs Rs 1.5. Two samples of the plastic bottles (mineral water and Pepsi) were tested in Switzerland for their potential use for SODIS project. As shown by Figure 3, the photospectrometric analysis showed that both the bottles have good transmittance and are suitable for the SODIS project.
- Analysis of Meteorological Data at Karachi: The thirty years meteorological data was gathered and analysed for maximum, minimum and mean temperatures, relative humidity, wind speed and number of rainy days. The data was collected from the three meteorological stations at Manora, Karachi Airport and Mauripur. The data reveals that Karachi receives a good amount of sunshine in the entire year with more than 5 hours of sunshine per day. The temperature during the day are sufficient to disinfect the water through SODIS approach. The number of rainy days per year in Karachi are only 10.6 which have low or no sunshine.
- Selection of Area for SODIS Testing: Shah Rasool Colony, an urban slum area located near to Defence Housing Authority and Clifton was chosen as an area for conducting field tests. This area was selected since Association for Protection of Environment (APE) has already done a primary solid waste collection project and where the community is mobilised. The socio-economic and community surveys have revealed that the diarrhoea and other stomach related diseases are rampant in the area. The households spend around Rs. 200 (US $ 4.4) per month on medication.
- Formation of Project Team: A project team for SODIS was formed consisting of personnel from APE and the community. The Team Leader was the Environmental & Sanitary Engineer, supported by Urban Planner, Sociologist and Social Worker from APE and two Helpers from the Community.

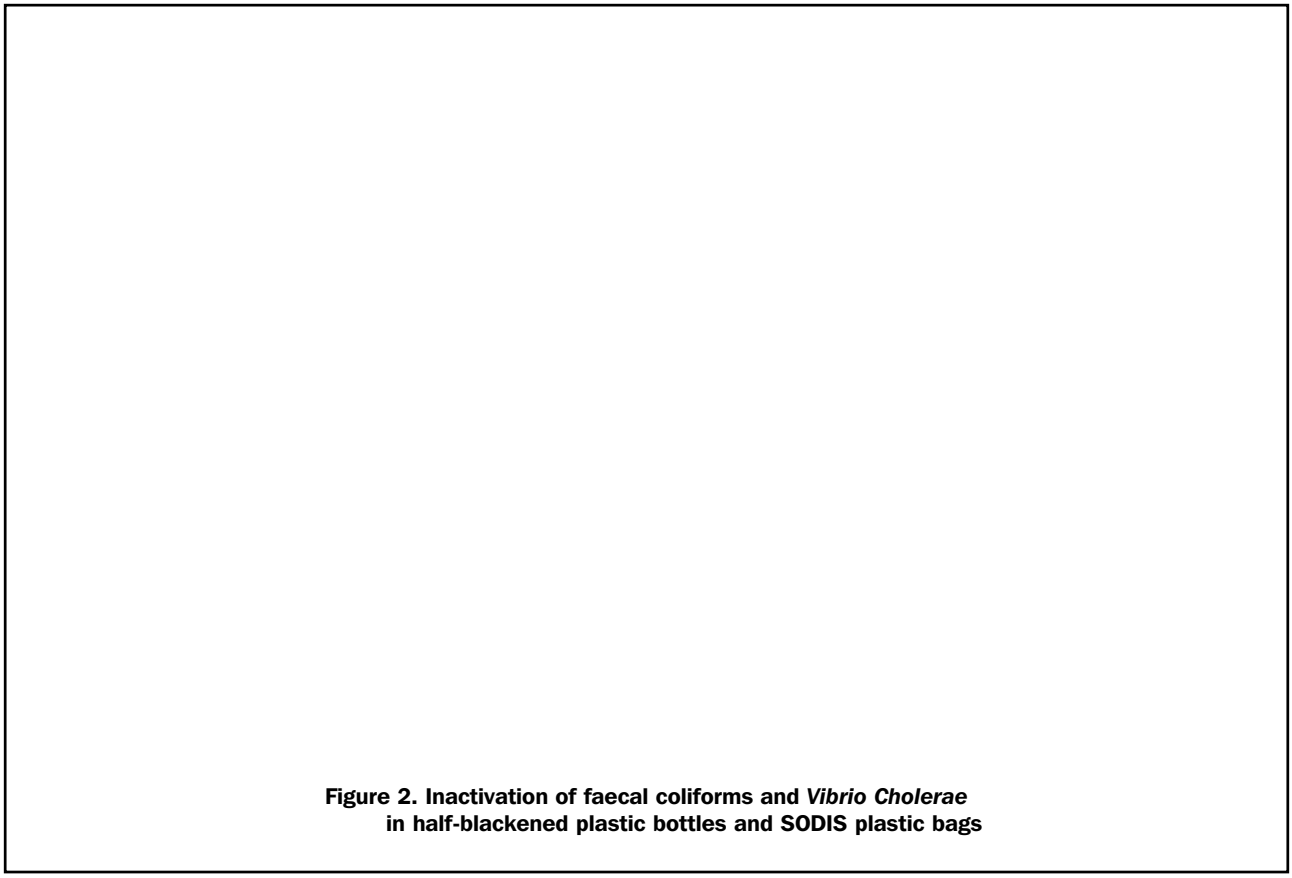

Figure 2. Inactivation of faecal coliforms and *Vibrio Cholerae* in half-blackened plastic bottles and SODIS plastic bags

- Preparation of SODIS Bottles: Based on the estimate that around 3 litres water is used per person per day for drinking purposes, two SODIS bottles each per household were made from Pepsi bottles which were half painted black. These plastic bottles were prepared and provided free of charge to the participating households. Special portable SODIS Plastic bag was also used in the area provided by SANDEC. This bag is made of two different polythene foils, a transparent one on top and black at the bottom equipped with a handle and screw plug.
- Testing of Raw Water: Laboratory testing of raw water obtained from the sample household was done to assess the water quality. The tests include for physical analysis (turbidity in NTU, suspended solids concentration in mg/l) and bacteriological analysis (faecal coliforms in CFU/100ml).
- Solar Disinfection of Water: The SODIS experiments were carried out in five households at different location in the locality for three consecutive days in February, 1998. The SODIS bottles and plastic bag were simultaneously tested at the defined location. The bottles and bags were filled with the tap water and kept on a roof of the household facing the sun. The experiment was started at 9 am. On all days of the experiment the weather conditions were good with bright sunlight and an average temperature of 29 °C during the day. The water temperature at the start of the experiment was 25 °C. In 4 hours the water temperature reached 50 °C in plastic bag and 4.75 hours for plastic bottles due to more surface area. The water was tested to ascertain the physical and bacteriological analyses. Different support material was also tested during the experiments. One plastic bottle was placed on a corrugated sheet roof of a household. The result showed that the temperature of 50 °C was reached 40 minutes earlier than the other bottle which was placed on the concrete roof.
- Acceptability of Water by the People: The bottles were cooled down naturally and by keeping in the cooler/refrigerator. The householders didn't notice any change in physical characteristics and willingly accepted the treated water. When explained the project and its significance the selected five householders started using the low cost technique for getting better quality of potable water. At the end of 2 weeks continuous usage, two householders affirmed that their minor children stayed healthy with no stomach disorders and diarrhoea, which usually occur once in a fortnight. This experiment shows the improvement in health, which needs to be further quantified by experiments and tests. Furthermore due to no labour or initial costs of the equipment, no matter of affordability was reported by any household. Two householders who were using boiled water for drinking purposes also shifted to the use of SODIS system due to savings in cost by use of this indigenous technology and savings of fuel and time. Furthermore it was noted that the SODIS water bottles can be cooled down easily as compared to the boiled

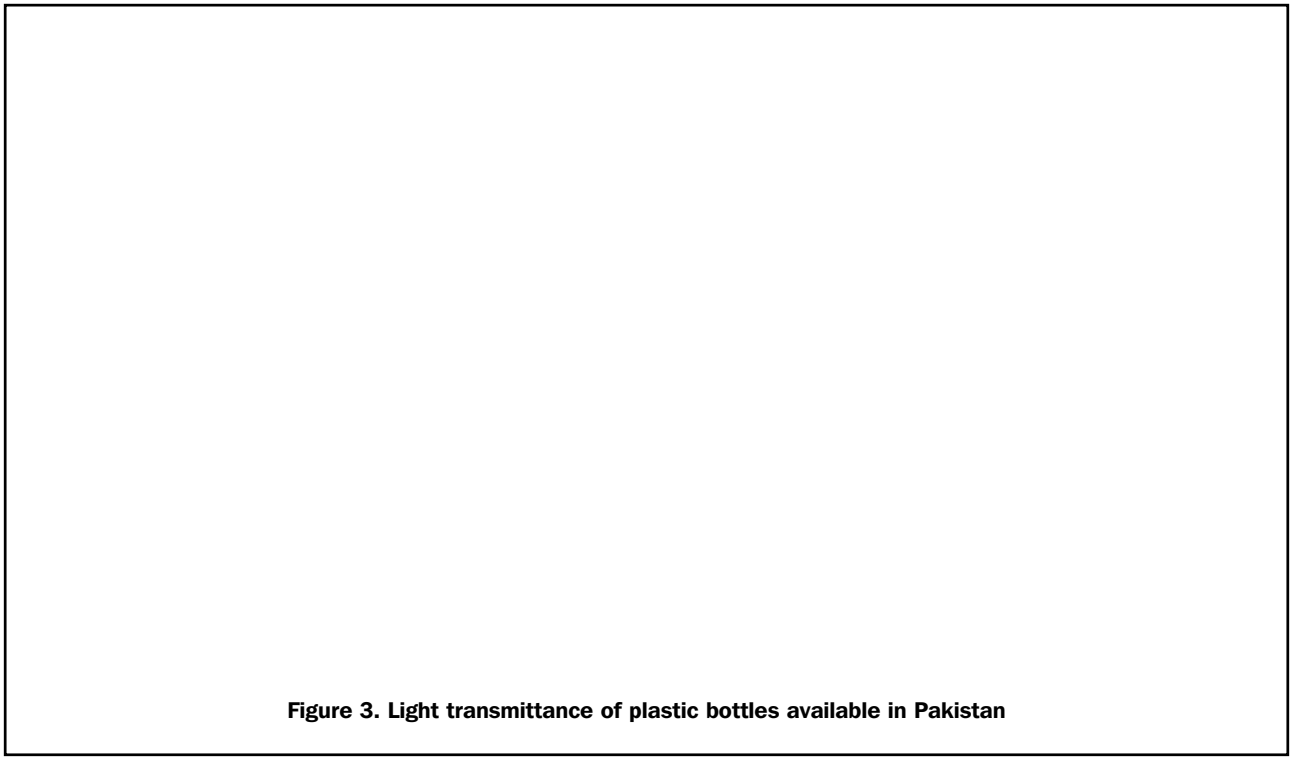

Figure 3. Light transmittance of plastic bottles available in Pakistan

water. The chances of contamination during cooling of boiled water is also avoided. The households also reported that SODIS is much easy and convenient due to non transferring of boiled water form the container to the bottles and cans. Water boiling is tedious, dangerous and annoying as it requires fire, careful handling of the hot pots and exposure to smoke. The SODIS water was also used by the households for cooking purposes. One household also gave the water from the SODIS bottle to the school children due to its convenience. SODIS bottles are easy to carry and transport and is thus the main reason for public acceptance. No household reported the problem of its affordability.

- Observations and Remarks: A.P.E. conducted a brain storming and informative session with the representative households and community leaders to discuss the aspects of SODIS with them. The informal observations and remarks are as follows:
  - SODIS bottles needs to be made and provided by outside organisations which are capable of producing it technically and hygienically. The bottles made by the householders were not having the consistent black colour at half of the bottle surface.
  - The community believed the water treatment process mainly due to explanation given by APE experts as they were already known by them. It was difficult to explain them scientifically and technically that such a simple process can be used to disinfect the water.
  - The question that why this method was not earlier used and practised in the country was asked and inquired several times.

    Organisations like APE are to be involved to conduct the water quality tests and to monitor it since in near future the water quality is not envisaged to be improved in the urban areas of the city.

    The most difficult task is to explain that why SODIS approach is better and more effective than the conventional boiling which is use since decades.

    Flat plastic bags were not socially accepted in the area as compared to the bottles due to its unusual shape and appearance. Another group thought the bags to be more effective since it looked to be made abroad and assessed to be more functional.
  - The SODIS water bottles are to be neatly and hygienically kept before and after use to avoid entrance of any foreign organisms during idling and no use.

Conclusions

The provision of safe and potable water to the growing population of major urban centres and rural areas remains a challenge to almost all developing countries like Pakistan due to economic, institutional and socio-cultural problems. Under such conditions, self reliant, sustainable and low cost water treatment system with use of indigenous methods are genuinely required to be used to combat against the occurrence of serious infections and communicable diseases rampant in the low income population. The research on SODIS is driven by the motivation to develop a reliable and inexpensive water treatment method for developing countries. SODIS as batch process satisfy the demand for safe drinking water of households while continuous flow systems can be used for schools, hospitals and neighbourhood groups and in emergency situations. The

experiments in Pakistan and other countries have shown that SODIS has great potential for use and replicability in contributing to the public health of the low-income population. A controlled dissemination of the SODIS approach, methods and testing is much required to transform the idea into reality.

Future actions

SANDEC has identified four major target groups who might benefit from SODIS project. They include rural population and rural institutions who are not served with potable water, people in urban slums and low income areas and lastly migrants and refugee camps where poor quality of water is supplied.

EAWAG has prepared a 15 minutes video and is publishing SODIS news on the subject as an informative newsletter to enhance information exchange between the project and partners. Further tests are required to be carried out at Karachi also, as is done in other cities of the developing world to assess its suitability for use by the population. SANDEC is in the phase of evaluating the demonstration projects after which national workshops will be organised in the seven participating countries.

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MARTIN WEGELIN is the Programme Officer at Water Treatment in the Department Water and Sanitation in Developing Countries (SANDEC) of the Swiss Federal Institute for Environmental Science and Technology (EAWAG).

REHAN AHMED is Consultant Environmental and Sanitary Engineer and President, Association for Protection of Environment (APE), Karachi, Pakistan.

NOMAN AHMED is Architect, Urban Planner and Coordinator of Urban Design Graduate programme at the Department of Architecture and Urban Planning, Dawood College of Engineering and Technology, Karachi, Pakistan.