

ECO-SAN : AN EMERGING SUSTAINABLE TECHNOLOGICAL APPROACH IN EDUCATIONAL INSTITUTIONS

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ABSTRACT

Inadequate water and sanitation facilities in the school environment have been reported as a major hindrance towards achievement of Goal 2.A and Goal 6 of worldwide Sustainable Development Goals (SDG). There is a growing need and pressure to provide sound educational tools in order to encourage capacity building and to support the world-wide implementation of ecological sanitation. This eco-friendly sustainable technology is based on the principle of safe reuse of nutrients of the human wastes in agricultural production, thus closing the loop of the human wastes production, treatment and reuse. This sanitation system not only intends to provide organic nutrient resources for ecological soil nutrient management but also gives sanitation related protection to school children. The technology is based on development of urine diversion dry toilets, biogas generation and composting of human waste generated night soil. Considering the poor sanitation and drinking water facilities of mainly rural Indian schools, various existing ecosan toilet designs can be potentially replicated in school premises with proper guidance from scientists, engineers and administrations in order to address the sanitation related problems with special reference to girl students and drinking water and hygiene problems. The main challenge for successful implementation of ecosan is to eradicate traditional belief and custom of hatred towards faeces and lack of training and awareness for the handlers and children for its operation and benefits.

Keywords: Eco-san, Waste to resource, Urine diversion toilet, School sanitation.

INTRODUCTION

The United Nations Millennium Development Goal 2.A is to ensure that the children everywhere will be able to complete a full course of primary schooling by 2015 (Tooley, et. al., 2007). Inadequate water and sanitation facilities in the school environment have been reported as a major hindrance towards achievement of this goal. Many schools in developing and developed countries lack adequate water and sanitation services, with associated potential detrimental effects on health and school attendance (Barrington, 2016). The recently adopted worldwide Sustainable Development Goals (SDG) that aim to reduce this problem and extend the access to basic sanitation (Johnson & Land, 2017) safe agricultural reuse of nutrients can provide a strong motivation for long-term adoption of improved sanitation among rural small holders (Dickin et al., 2018). There is a growing need and pressure to provide sound educational tools in order to encourage capacity building and to support the world-wide implementation of ecological sanitation. There is also a need for a broad analysis of existing curricula and education systems in both formal educations at all levels and continuing education in water and environment related disciplines, with a view to introducee the holistic concept of ecological sanitation. In developing countries and countries in transition, ecological sanitation education and training is even more important and urgent, especially in the context of achieving the Millennium Development Goals for sanitation and environmental sustainability (Langergraber & Muellegger, 2005).

The connection to ecological sanitation (Eco-San) that allows for the safe recycling of nutrients to crop production in such a way that the use of non-renewable resources is minimized. In a specific local setting, the eco-san aims to meet socioeconomic demands, prevent surface and ground water contamination, sanitise urine and faeces, recover nutrients for food production, and conserve resources like water and energy. The applied technologies may range from natural waste water treatment techniques to compost toilets, simple household installations to complex, mainly decentralized systems (Mahmood et al., 2013). Therefore, EcoSan is not just a poor people solution, with low standard; it is more a number of appropriate solutions for different specific local situation. In order to support Sustainable Development Goals 2 (zero hunger), 6 (clean water and sanitation for everyone), and 13 (climate change solutions), this closed loop sanitation system not only intends to provide organic nutrient resources for ecological soil nutrient management but also gives sanitation related protection to school children. In order to gain knowledge for its acceptance and implementation potential in Indian rural sector, the present review has been done.

OBJECTIVE OF THE STUDY

There is an urgent need for better water and sanitation systems, not just in family residences but also in educational institutions. It should enable the end-users to develop, plan and implement eco-sanitation systems that are hygienically safe, socially acceptable, economically feasible,

environmentally sound and technically appropriate. One of the finest places to teach the younger generation about the value of good cleanliness and the advantages of better sanitation is probably in the classroom. Therefore, it seems sense to include a training element for better cleanliness in the school itself (Shangwa & Morgan, 2009). The majority of government schools in rural and backward areas of India struggle with poor sanitation system, which might lead to several illnesses of the students. Therefore, this study will help us to discuss the implementation and adoption potential of emerging Ecosan technology which might resolve this situation by providing good environmental feedback.

METHODOLOGY

For the purpose of the study an extensive literature review has been done and related information was collected, synthesized, analyzed and finally summarized for documentation from the critically screened literature.

BASIC PRINCIPLE OF ECOLOGICAL SANITATION

Ecosan is based on the principle of treating the human wastes for pollution and health hazard prevention by using the reuse and recycling principle to use its nutrients in agricultural production thus making the concept a sustainable one (Langergraber & Muelleger, 2005). The “sanitises and recycles,” or closes the loop of the circular flow of nutrients, by adhering to the three guiding principles of (a) Preventing pollution rather than trying to control it; (b) Treating urine and faeces; and (c) Using the safe treated products for agricultural use (Hazra et al., 2023), (Fig 1).

Eco-sanitation works on principle of self-designing the nature based function of utilizing materials from one living system by another living system (Jana et al., 2012) with a supplementary advantages of conserving water, energy, and reducing pollutants (Pandey, 2017; Maurya, 2012). Returning sanitized human urine and faeces to the soil helps to restore the natural cycling of life-building elements, which has been disturbed by conventional sanitation methods (Jonsson et al., 2005) with subsequent nutrient from waste being recycled to crop growth (Jothimani, 2012; Devadula et al., 2015).

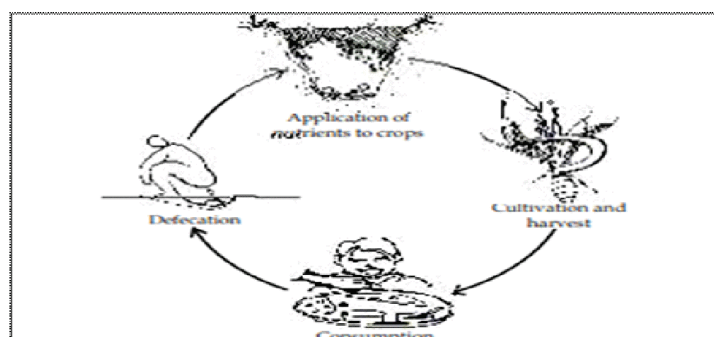


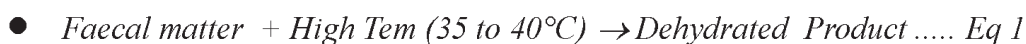
Fig 1: The Closing Loop of Ecosan (Source: Chariar & Sakthivel, 2011)

WASTE TO RESOURCE CONCEPT

Hazardous microbes in human excreta must be removed in order to maintain “resource flows” in the context of sanitation with “reuse products” or “other outputs” and avoid significant barriers to its commercialization and nutrient recycling to soil in regions with significant horticulture export (HEDF, Moya et al., 2019; Tixier & De Bon, 2006). There are an increasing number of treatment methods available to make excreta safe and controllable for re-use (Jensen et al., 2008) that improve individual well-being and greater sustainability.

i) *Urine Diversion & Dehydration Methods*

The easiest treatment for transforming faeces into a product that is acceptable for reuse or disposal is dehydration by adding dry organic material (such as lime and ash) and long-term storage at a high ambient temperature (Eq 1); (Senecal & Vinneras, 2017). Dehydration can be done on-site in dehydration vaults or off-site in dehydration beds or bags that are humidity-protected (Tilley, 2014). On-site dehydration vaults collect, store, and dry (dehydrate) faeces (e.g. in double-vault UDDTs; Spitzer et al., 2018). Increase of temperature (>35%), pH (alkaline treatment) and minimisation of the moisture content (<25%) can significantly accelerate the process. Lime and ash will boost the pH, whereas sawdust will absorb moisture (Deegener et al., 2016).



ii) *Energy recovery*

According to Jaeger & Machry, 2014, thermo dynamic analysis investigates the potential of human waste as an energy for self-sustaining sanitary systems in the future. According to Onabanjo et al. (2016), the “Nano Membrane Toilet (NMT)” is an original, small-scale sanitary solution that handles human waste locally, using a small-scale gasifier to produce syngas from organic or fossil-based materials at high temperatures (>700°C) Eq 2, (Fig 2) by utilizing the chemical energy of settled solids from human excreta, which include wet faecal matter, despite their high moisture content.



Through this process it is observed that energy recovery from human excreta and kitchen waste can offset the energy consumption of the sanitation system and the energy surplus can even be 1067.70 kJ·PE⁻¹·day⁻¹. (Xu et al., 2021). Moreover, Liu *et al.*, 2014 has proposed the self-sustained system for the conversion of settled solids from human excreta to power that utilises plasma gasification and solid oxide fuel cells with specific net power output of 194.4 to 357.3 Wh/kg settled solids, depending on whether the faecal matter was dried or not prior to plasma gasification (Hanak et al., 2016).

In Indonesia there had been a report of biogas production of 2,350.7 MJ/day or 652.97 kWh/day from human excreta (2500 kg/day) which was further used for energy consumption (Andriani et al., 2015) and if hygienization is ensured, the end product (decomposed sludge) can be used as a fertilizer/soil conditioner (Di Matteo et al., 2017) in agriculture or horticultural field.

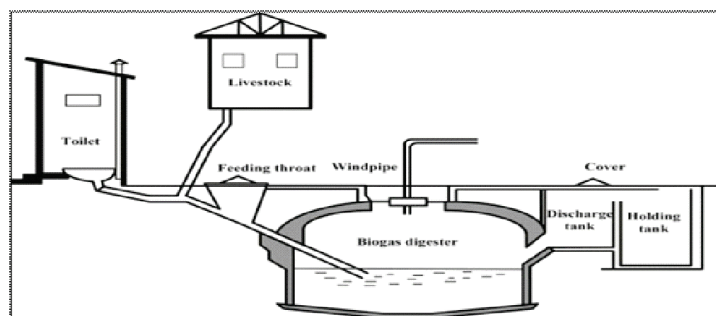


Fig 2: Three Link Biogas Toilet (Source: Wang et al., 2016)

iii) Organic farming

Human waste often known derogatorily referred as ‘night soil’ contains the major plant nutrients in different proportion (Table 1) which is being treated and used as a possible source of organic compost in agricultural field with high crop yield in garden of school/universities. However, preserved urine has more potential than fresh urine because the urea within promotes microbial activity and causes the urea to be converted to nitrate, which is then ingested by plants in agricultural fields or by phytoplankton in fish ponds (Jana et al., 2012; Hazra et al., 2023).

Table 1 : Nutrient Potential of Ecosan waste

Plant Nutrients	Urine	Faeces	Grey water
Nitrogen (N)	80 - 90%	12 - 15 %	8 - 10 %
Phosphorus (P)	50 - 55 %	25 - 30 %	18 - 20 %
Potassium (K)	60 - 70%	25 - 30 %	12 - 15%
Other's substance	creatinine (6%), ammonia (7%) free amino acids, Ca^{2+} , K^+ , Na^+ , NH_4^+ and SO_4^{2-} , PO_4^{2-} and Cl^-	Magnesium (Mg) and selenium (Se), Carbon (40 - 45%), CaO (4 - 5%)	NO_3^- - <0.1 - 21.4, Na - 29 – 230 mg/l
References	Kirchmann & Pettersson, 1995; Hazra et al., 2023; WHO, 2006; Hazra et al., 2023		

In nature, microorganisms and other soil biota will typically breakdown organic waste or materials (such as leaves, food scraps, human excreta and others) by the process of composting. Composting can be done in latrine pits or separate heaps by the decomposition of organic waste such as faeces, toilet paper, vegetable peels and wood shavings or mulch. This method balances the carbon-nitrogen ratio and reduces nitrogen levels. A second pit should be available for composting when full, and the final product should reach 55-60°C for several days to make it safe for use as a fertilizer. Another composting method of vermicomposting involves culturing earthworms (*Eisenia foetida*) outdoors in beds or confined chambers in the presence of waste materials, reducing carbon and nitrogen levels through microbial activity (Yadav et al., 2010). To address the detrimental effects of organic waste and to protect the school environment, sustainable organic waste management becomes crucial.

DESIGNS OF ECOSAN TOILETS

Human faeces can be utilised to make fertiliser and biogas since it is a rich source of nutrients. Thus to use the potential of human excreta, a newer form of toilets has been developed. Among these, the following are the toilets that may be employed in educational institutions most effectively:

Dry Toilets

Ecological sanitation, often known as “dry box toilets,” has been successfully implemented in a number of developing nations, including China, Japan, Mexico, Ecuador, and, more recently, Zimbabwe and South Africa. In this type of toilet human excreta (both urine and faeces or urine/faeces) is collected into a single and multilayered chambered tank and continuous flushing with dry organic material such as lime and ash. The basic functioning principle of a dry toilet is the fact that liquids are separated from the solids, either from source (by UDDT) or later by composting toilet (Aburta et al., 2020).

Mixed Type Toilet : Many countries have been implemented a special kind of dry toilet called “Mixed Type Dry Toilet” with a fundamental goal to handle both faeces and urine that should be returned to the soil by generating the most effective humus possible. There are varieties of mixed toilet briefly described below:

a. Arborloo : Arborloo is a shallow pit (approximately 1.0 to 1.5 m deep) i.e. filled with excrement and dirt/ash and then covered with soil and a tree planted on top of the nutrient-rich pit will vigorously grow (Sklar & Faustin, 2017). Many poor countries, including as Zimbabwe, Malawi, and Africa adopt arborloos in rural regions.

Advantage : Low cost, lower risk of pathogen transmission.

Disadvantage : New pit must be dug; the old pit can't be reused, not suitable with a high groundwater table.

b. Tree Bog : A tree bog is essentially a managed compost heap with moisture or nutrient-hungry trees (willow, berch etc.) added to improve its performance. It may be called a permaculture design since it is a system for converting urine and faeces to biomass without the requirement for excreta handling, mainly practised in U.K (Deakin, 2009).

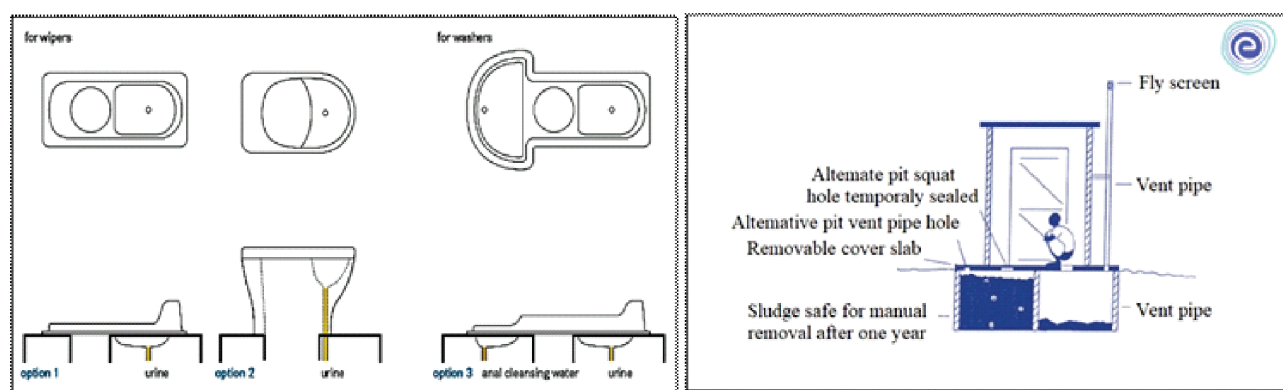
Advantage : Simple technique to use, conservation of water, end product can be used as a good fertilizer.

Disadvantage : The planted species should be nutrient “hungry” and ideally be harvestable too.

Separating / Urine Diverting Dry Toilet : A urine-diverting dry toilet (UDDT) is a form of dry toilet with urine diversion that may be utilized in a number of settings across the world to offer safe, affordable sanitation (Zhuang et al., 2021). The UDDT is designed in such a way that urine is collected and drained from the front of the toilet, while faeces are discharged via a wide chute (hole) at the back (Fig 3). Depending on the collection and storage/treatment technology that follows, drying material such as lime, ash or earth should be added into the same hole after defecating (Trimmer, et al., 2016).

A specifically constructed pedestal diverts the urine at the source, preventing it from mixing with the faeces. A pit isn't required because the entire building can be built above ground or even inside the home (Fig 4). The ash absorbs moisture and helps to keep odours and insects at bay. Desiccated faeces are a wonderful soil conditioner, and urine, which is high in nitrogen, phosphate, and potassium, is an excellent source of fertiliser (Lalender et al., 2013).

Fig 3 & 4 : Schematic Representation of Urine Diverting Dry Toilet (Source : Tilley et al., 2014 & Mnkeni et al., 2009)



Emerging Eco-toilets : Recently, new eco-toilets have emerged that use extremely little water, allowing for greater cleanliness and water conservation that may also use in modern school and universities. These type of toilets are mainly of two types :

- **Microflush Toilet :** The micro flush toilet is a low-cost toilet that is sustainable, ecologically friendly, odour-free, and fly-free that isolates waste and flushes with a few ounces (1 cup) of grey water (Laundry and Toilet flushing) & from a previous user's hand wash. The solids are composted in an aerobic process that is aided by simple earthworms (*Eisenia foetida*), and other macro-organisms, leading in significant bulk reduction and pathogen elimination, a procedure that has outperformed standard latrine microbial composting (Davis, et al., 2013).

Advantage : Less amount of water required, energy saving, end product can be used as compost or vermicomposting.

Disadvantage : Installation cost is comparatively high, proper knowledge should be required.

- **Vacuum Toilet :** Vacuum toilets are flush toilets that utilize suction to remove faeces and urine, using the least amount of water possible (0.5 - 1.5 litres). It provides the same degree of comfort as regular flush toilets while also saving money because to the reduced quantity of flush water used. These systems are applicable both in large and small buildings, trains, ships and airplane (Gao, et al., 2019).

Advantage : Flexible and convenient, facilitates reuse of urine and faeces, hygienic.

Disadvantage : Depended on electric power supply, bulky material (i.e. sanitary napkins) can lead to clogging.

PRESENT SANITATION STATUS IN EDUCATIONAL INSTITUTION

Every child has the right to a high-quality education, which includes having access to WASH services while they are in school for drinking water, sanitation, and hygiene. A large amount of a child's day is spent at school, where water sanitation and hygiene (WASH) services may have an influence on girls' learning, health, and sense of dignity. The Sustainable Development Goals' inclusion of WASH in schools (targets SDG 6) shows that their significance as essential elements of a "safe, non-violent, inclusive, and effective learning environment" and as part of "universal" WASH access, which emphasises the need for WASH outside of the home, is being recognised more and more (WASH, 2018).

Inadequate water supply, sanitation, and hygiene conditions in educational institutions, particularly schools, can negatively impact health and learning outcomes, especially for girls (Sinha & Paul, 2018). These conditions increase children's susceptibility to environmental health hazards, such as helminthes infections, long-term exposure to chemical contaminants, and diarrheal diseases (El-Nadi et al., 2017). In 2016, 66% of schools had improved single-sex sanitation facilities, while 12% had limited or unimproved facilities. 23% of schools worldwide had no sanitation service or relied on unimproved facilities (UNICEF, 2018).

On this basis it is estimated that over 620 million children lack basic services and limited or no sanitation at their schools, with 53% of schools having basic hygiene facilities. In 2016, 11% had

limited services, and 36% had no handwashing facilities. Over 850 million children lack basic services and limited or no handwashing facilities. Lack of water and sanitation facilities for menstruation in schools leads to discomfort and avoidance (Sivakami et al., 2019). Interventions like water and hygiene can decrease absenteeism among girls, especially in developing countries with high drop-out rates. Ensuring women and girls can continue attending educational environments is crucial for achieving the Millennium Development Goals of universal education and promoting gender equality and empowerment.

However, it is studied that nearly 89% of co-education schools have at least one toilet unit for boys and girls, while only 32% have separate toilets for teachers. 83% of rural and urban schools lack accessible toilets. Only 76% of rural school toilets had door with latch/bolt, 13.3% lack proper doors, and 5% lack roof, ventilation, and natural light. Hand washing facilities are accessible to all children. There is a shortage of teachers trained in sanitation and hygiene education. But as a result of COVID-19, the future of education depends on the provision of water, sanitation, and hygiene services (Ashraf et al., 2020).

IMPORTANCE OF ECOSAN IN EDUCATION

According to the Bellagio Principles, 2000, “universal access to safe environmental sanitation, within a framework of water and environmental security and respect for the economic value of wastes” ensures human dignity, quality of life and environmental security at household level which should be responsive and accountable to needs and demands in the local and national setting. Based on this principle, Ecosan education aims to equip people with the skills to build, plan, and execute hygienic, socially acceptable, economically viable, environmentally sound, and technically adequate eco-sanitation systems (Werner et al., 2009). Therefore, integration of many sectors in urban environmental planning and practise should be covered in ecosan education. Even while the fundamentals of ecological sanitation are “universal” in the sense that they apply to all projects, different stakeholders engage diverse target groups who have varying histories, goals, and capacities for accepting the “new paradigm” of ecological sanitation.

APPLICATION OF ECOSAN IN EDUCATION SECTOR

A. Implementation of UDDT in organic farming: Ecosan technologies, such as UDDT toilets, can be built and maintained together with students and teachers (Shangwa & Morgan, 2009), arborloo toilets on the other hand, are often suitable for schools in rural areas. UDDTs are more appropriate than pit latrines in densely populated areas, in regions with a high groundwater table, hard rock, crumbling earth, or seasonal flooding because they do not rely on soil infiltration. In school gardens, students can learn how to increase the yield of vegetables by safely applying treated excreta (such as urine, dried faeces, compost, irrigation water) as fertiliser and soil conditioner through ecosan technology (Ingle et al., 2009). If organic waste is not properly

managed, it may have a detrimental effect on both the school's environment and the pupils' level of health. Therefore, a solution to the issue of using organic waste is required in order to promote a healthy and clean environment and it can help schools economically (Cicilia et al., 2018).

- Established in 1997, the ACTS Rayasandra Campus for Higher Education in Bangalore, India, houses the ACTS Academy for Higher Education, male and female dormitories, a guest house, staff housing, a kitchen and dining area, and a vocational training facility (June 1st, 2006). Through installing UDDT, they successfully achieve sustainability by producing organic fertilizer and Ecosan light in addition to basic sanitary services (GTZ, 2006).
- Adarsh Vidya Mandir School in Badlapur, Maharashtra, will provide new sanitary facilities for students and staff (drafting in August 28th, 2006). Two alternatives include ceramic squatting pans and a two-storeyed urine-diversion dehydration toilet block. The school plans to use digested sludge and urine collected from urinals on agricultural plots, with potential cooperation with local universities (GTZ, 2006).

B. Potential source of Bio-fuel : Pour-flush toilets connected to a biogas plant and additional treatment components are examples of Ecosan technologies that can provide biogas for cooking in place of either firewood (preserving the vegetation surrounding the school in the process) or saving money by eliminating the need to purchase LPG (liquefied petroleum gas) cylinders (Ingle et al., 2009).

Based on Ecosan application in Adarsh college - Badlapur, 2009 it is observed that the maximum estimated output of biogas is 6.8 m^3 , which is equal to 4.8 m^3 of earth gas or 4 litres of diesel. LPG would typically be needed to power the gas cooker, but when biogas is utilised instead, LPG is conserved. As a result, these systems contribute to energy conservation through the use of biogas, which powers a gas cooker in school kitchen and at the neighbouring Ecosan Exhibition Hall (Barreto dilon, 2010).

C. As an awareness training programme: The University of Kalyani's International Centre for Ecological Engineering (ICEE) aims to provide environmental awareness training, courses, and research opportunities in ecological engineering, particularly in ecological sanitation. The proposed sanitation concept includes urination-separation dehydration toilets (UDDT) urine collection, and greywater reuse for gardening and irrigation along with potential source of organic fertilizer from human excreta (GTZ, 2006; Pynnonen, 2012).

- 1st Draft & 2nd Draft, report on the Ecosan Prefeasibility Study "International Centre of Ecological Engineering at the University of Kalyani, West Bengal" (July 14th, 2006) & (August 27th, 2006) respectively.

Through this training program, they have imparted comprehensive knowledge of Ecosan, a waste to resource concept with favourable environmental feedbacks.

D. Ecological sanitation in education and training : The inability to fulfil the rising demand for the adoption of ecological sanitation is currently seen as a major limiting issue. In India, the government is planning to introduce sustainable sanitation as part of the curriculum in schools starting with the 10,000 Central Board of Secondary Education (CBSE) schools through its Urban School Sanitation Program (www.schoolsanitation.com). Here a whole range of measures and activities will be included such as : • Awareness raising through inclusion of sanitation as curriculum in the schools • Preparation of school sanitation manual as a handbook of best practices with reuse of water and advanced waste management in schools • Sanitation rating of schools and appreciation through National Urban School Sanitation Awards • Orientation program for the school principals • Inclusion of sanitation as a requirement for school accreditation/affiliation by CBSE • Creation of the brand value for the sanitation initiative by having a sanitation brand ambassador and sanitation week. The long term goal is to ‘Educate them young’ to achieve improved sanitation (Panesar et al., 2006).

CHALLENGES FACED

Every year, students are rotated and replaced in schools, along with teachers and school administration on occasion. Therefore, lessons learned about how to operate and maintain UDDTs, anaerobic treatment facilities, and how to use biogas, water, and nutrients properly could be forgotten by the school. Therefore, it is imperative that this information be continuously transferred to newly arriving students and professors in order to prevent mismanagement and the abandonment of ecosan installations. Therefore, it is advised to incorporate ecosan and sustainable sanitation into as many school events as you can to help students incorporate them into their daily lives.

The main risks associated with ecosan result from either mismanagement of the facilities (by, for example, not allowing enough storage time or allowing water into a dehydrating system), or poor construction of facilities. The outcome of both of these is that the pathogen content of the waste is not reduced to safe levels, putting a selection of stakeholders at risk, namely those responsible for emptying the facilities. Moreover, untrained users can’t continue the safe operation of ecosan toilet facilities in schools. Handling human waste should be done by faecophilic society people and not faecophobic people for its sustainability. Another potential barrier to successful ecosan is the lack of school communities’ willingness to take part.

CONCLUSION

The thrust on improving our environment by proper sanitation management is crucial in our battle to clean up our rivers, lakes, and seas, which mostly receive the major bulk of untreated wastewater. Thus, closing the resource loops can finally prevent the conflict of planetary

boundaries. Even though there is a great need to increase sanitization practises and their potential for reuse and recycling in developing nations like India, there has been relatively little usage of eco-sanitation and very little understanding of it. So meeting the sanitation SDG also opens the door of “sanitation as service” and “waste into wealth” as a key pillar in the vision of a sanitation based economy creating job opportunities, and entrepreneurial development operated through right service delivery models, policies, funding, and regulatory and institutional frameworks tailored through local reality.

Establishing and promoting ecosan toilets in our educational institutions (mostly rural) need a revolution in our thinking and acting processes, focusing mostly on a private-public partnership in order to achieve the ambitious SDG goals. This will definitely result in a leap in the socially important development of children’s lives, health, and overall cognitive development by ending open defecation. Attempts will be made to minimize people’s traditional mind-set and deep beliefs of revolting against faeces. Therefore, in order to advance in the goals established by organizations that make decisions at the global level, like the WHO, scientists and workers must continue to concentrate on the engagement of rural communities or the rural community level decision makers.

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