Despite the fact that access to water and sanitation are known as integrated elements of National development, the most valuable public health intervention and fundamental need of human being remain as a major concern in India and in many others developing countries. In 2000, India signed United Nations Millennium Development Goals (MDG) that includes 8 goals, 21 targets and 60 indicators reached its deadline in December 2015. MDG-7 target was to halve the proportion of population without access to safe drinking water and basic sanitation that may play significant role to achieve the target of MDG-4 i.e.; reduce child mortality rate. But India has made “moderate progress” and failed to achieve it as compared to its neighbor countries like China, Bangladesh, Pakistan, Sri lanka that have made good progress (UNICEF & WHO,2015). Figure 1 shows between 1990 to 2015 more than 35 percent population of India’s neighbor countries gained access to adequate sanitation and open defecation rate drastically came down in contrary only 28 percent populace of India gained access to adequate sanitation and there is open defecation rate is still significant if compared to other countries. During MDG periods though open defecation rate had declined in all regions, but access to improved sanitation among urban, urban slums and rural regions are significantly different. In India access to improved sanitation is higher in urban areas than in rural and urban slum areas. Worldwide 96 and 82 percent world’s urban population has access to safe clean water and improved sanitation facility and rural population has 82 and 51 percent, while in India according to 2015 data still 44 percent population defecates in open in which 10 percent belongs to urban areas, 61 and 67 percent belongs to rural and urban slum areas respectively (UNICEF & WHO, 2015). Rapid urbanization due to increased migration of people from rural areas to cities for employment over the last century [from 25 million in 1901 to 1326 million in 2016 constituting around 32.4 percent of the total population in the country] led to overcrowding of cities especially that of urban slums in India. At present, 17.7 percent of urban population lives in slums1 (Census, 2011) 

1 Slums are characterized by crowded living ambiance, unhygienic environment and lack of basic amenities such as garbage disposal facilities, drainage system, water and sanitation. (MHUPA, 2010)
Urban areas have failed to meet the demands of this increasing population pressure resulting in large gaps in provisioning of basic amenities like water and sanitation facilities. The access to basic sanitation, drinking water and health of the urban slum is significantly worse off than the rest of the urban population and is often comparable to the health conditions in rural areas (Islam et al, 2006; Montgomery & Hewett, 2005). Despite the fact that several national and international programs were launched over the time to increase the coverage of sanitation but rural and urban slum India show sluggish and uneven progress and still has a long way to go.

Figure-1 Proportion of the 2015 population that gained access to sanitation since 1990(%) and open defecation: percentage of population in 2016


India needs to bridge the gaps in access to sanitation among urban, rural, urban slum, rich and poor. MDG did not much focus on sustainable development, sustainability challenges and innovation system; so that a new set of transformative “Sustainable development goal (SDGs)” as well as “Swatch Bharat Mission” adopted by India intends to make a “clean India”. Sustainable Development Summit held on 25 September 2015 carries forward to make MDG sustainable
with a slogan of achieving sustainable development goals. UN member States signed the 2030 agenda for Sustainable Development, which consists of 17 goals. The SDGs-6 renews efforts to ensure availability and sustainable management of water and sanitation for all by 2030. Any national and international program can’t achieve their target until understand sustainability challenges and focus on innovation system framework to address the challenges. There is clearly a need to call policymaker and professionals to better anticipate inadequate sanitation risk in consequence to increase national financial burden, poor children health and hammering social dignity.

This paper presents an exploratory analysis of impact of inadequate sanitation in consequence with different dimensions, identifies and addresses the challenges which are hindrance towards pathway to achieve sustainable development Goal-6 using innovation system framework.

Objective:

1. To study the impact of inadequate sanitation in consequence to national development.
2. To identify the structural and functional challenges that hampers the expected outcomes of Sustainable Development Goal-6.
3. To design theoretical framework / pathways to sustainable sanitation using innovation system to address the challenges.

Sanitation: A Problem

Inadequate sanitation has a multidimensional negative impact on children health, education for girls, environment, social dignity and national as well as individual economic growth. All over the world, people at the bottom of the pyramid are deprived of sanitation and technological solution. Unhygienic living conditions trigger a propensity to fall sick more often and increased recovery time and costs. The lack of sanitation gives rise to infectious diseases like diarrhea, cholera, typhoid, intestinal nematode infections, poliomyelitis, water borne viral hepatitis, trachoma etc are mainly caused by enteric pathogens including viruses, bacteria and parasites that primarily or exclusively transmitted by the faeco–oral route leading to higher public cost for treatment and productivity loss. In India, infectious diseases share 31.9% of total burden of diseases in which 10% transmitted by faeco-oral route (NCMH, 2005). In India, diarrhea second leading contributor to the global disease burden caused the deaths of more than 2 million children younger than five years per year, accounting directly for 12.6 percent of child deaths (Liu et al
2012. World Health Organization (WHO) estimates that in 2011 around 240 million children in India needed preventive chemotherapy treatment for soil transmitted helminthes and more than 1 million children suffer from typhoid in 2013 associated with inadequate sanitation. Also lack of clean air and environment pool ventilated living condition would lead to respiratory disease such as pneumonia, tuberculosis, asthma, chronic respiratory disease etc. In India, every year more than 4 million episodes of severe pneumonia and 0.32 million of all cause pneumonia (biggest killer) deaths occur in children younger than 5 years.

Figure 2 shows co-relation between percentage of open defecation and under five children death and death caused by diarrhea and pneumonia among BRICS countries. In India high rates (50%) of open defecation may be one determinant for high rates of sanitation related diseases. In other countries such as South Africa, Brazil, China and Russia open defecation is much less so consequently children death and occurrence of diarrheal and pneumonia is also less than India.

![Figure 2: Percentage of open defecation, Children death, and death caused by pneumonia and diarrhea among BRICS countries (2015). (*Children under 5 years)](http://data.worldbank.org/indicator/SH.DYN.MORT)


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3 [http://cbhidghs.nic.in/writereaddata/mainlinkFile/Health%20Finance%20Indicators-2013.pdf](http://cbhidghs.nic.in/writereaddata/mainlinkFile/Health%20Finance%20Indicators-2013.pdf)
In India inadequate environmental sanitation, hygiene and quality and quantity of water also responsible for highest contribution of malnutrition and stunting prevalence in the world that hurts cognitive function, physical development, immune systems and contributes to poverty by impeding people’s ability to lead productive lives (Schmidt, 2014; Dobe, 2015). An expected 50% underweight or malnutrition is associated with repeated diarrhea or intestinal nematode due to insufficient sanitation and absence of safe drinking water (Prüss et al. 2008, UNICEF, 2011).

Table 1 shows globally and Indian figures of underweight, stunted growth wasted and severely wasted children. Child in the urban slum and poorest household are more than twice as likely to be malnourished as child in richest household.

<table>
<thead>
<tr>
<th>Children under five years</th>
<th>Global (in millions)</th>
<th>India (in millions)</th>
<th>India (in percentage)</th>
<th>Total worldwide contribution of India (in percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>99</td>
<td>56</td>
<td>48</td>
<td>56.5</td>
</tr>
<tr>
<td>Stunting growth</td>
<td>161</td>
<td>62</td>
<td>51</td>
<td>38.5</td>
</tr>
<tr>
<td>Wasting</td>
<td>51</td>
<td>16</td>
<td>13</td>
<td>31.37</td>
</tr>
<tr>
<td>Severe wasting</td>
<td>17</td>
<td>4.5</td>
<td>4</td>
<td>26.4</td>
</tr>
</tbody>
</table>

Source: [http://www.worldhunger.org/articles/Learn/child_hunger_facts.htm](http://www.worldhunger.org/articles/Learn/child_hunger_facts.htm)

Various studies revealed that sanitation, hygiene and improved water supply helped reduce the morbidity and mortality due to infectious diseases to a great extent. (Prüss et al., 2002; Nath, 2003; Mara et al., 2010). In India, Mizoram declared as an open defecation free state reported a 13 percentage-point decline in stunting and five percentage points decline in underweight children. Not only Jharkhand, Bihar, Uttar Pradesh were reported as highest open defecation states accounted for 58, 72 and 73 percent respectively, but also contributing to the highest malnourishment accounted for 42, 37 and 32 percent as well as stunting 47, 49 and 50 percent prevalence respectively.⁴

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Impact of inadequate sanitation on education

Worldwide, one in five children between the ages of 10 and 15 are out of school (UNESCO, 2010) just due to inadequate and unavailability of sanitation facility. Girls in developing countries strangely drop out of school, particularly around puberty due to absence of sanitation facilities in many schools worldwide. Absence of sanitation facilities in schools not only cause girls to miss school on their menstrual days but may also responsible for verbal and physical harassment. Parents don’t want to allow their girls to go to school at pubescent age if sanitation facility not available (Kirk & Sommer, 2006; World toilet day advocacy report, 2014). Girls need privacy and safety at any place but unavailability of sanitation facility in school excluding them to complete their education and create gender disparity in education. A study undertaken in Bangladesh revealed an 11 % increase in girls’ enrolment mainly due to the provision of sanitary toilets (Technical paper series/IRC).

In rural and urban slum areas illness due to repeated episodes of diarrhea and worm infection may be also a significant reason to miss classes. Inter--relation between sanitation and education have not been understood in depth with respect to child education improvement. In most of the literature, inadequate access or unavailability of sanitation facilities in school has been not listed as the reasons for rising drop-out rates in rural/urban slums girls. However, school sanitation has traditionally been neglected, but now “Swatch Bharat Mission” initiative also focused to provide sex –specific latrines in all government schools.

Economic and social impact of sanitation

Inadequate sanitation causes increased national financial burden associated with the direct costs of treating sanitation-related illnesses, lost income through reduced or lost productivity, incomplete education of girls, access time as additional time needed for accessing shared toilets and open-defecation sites compared to using a private toilet within the household, and tourism impacts includes Potential loss of tourism revenues, and the economic impacts of gastrointestinal illnesses among foreign tourists. World Bank study says, Inadequate sanitation in India amounted to a loss of 2.4 trillion ($53.8 billion) in 2006, in which health share wider loss accounted 1.75 trillion ($38.5 billion), which was 72 percent of the total impact and access time

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5 https://sanitationupdates.wordpress.com/2015/01/20/yes-hygiene-and-school-enrolment-are-directly-proportional/.”
and tourism contributed 20 and 0.5 percent. In purchasing power parity (PPP) terms, the adverse economic impact of inadequate sanitation in India was $161 billion, or $144 per person. These economic impacts were the equivalent of about 6.4 percent of India’s gross domestic product (GDP) in 2006 (World Bank, 2011).

Inadequate sanitation facility also directly co-related with the increased risk of social issue such as rape and sexual harassments of female. There are several cases reported by media that ladies assaulted and raped when they go outside to defecate at early morning or late evening. In Bihar more than 870 assaulted instances reported just due to absence of sanitation facilities in 2012 (Tewary A, 2013). In Uttar Pradesh two young women were stuck and murdered, when they were looking for private spot for defecate (Soutik B, 2014). Whereas this story stood out as truly newsworthy, the truth of the matter is that many women face provocation, attack, and assault when looking for some measure of privacy. The open defecation pattern not only exposes woman to dangers of sexual assault, but also to snakes, insects, scorpion bites, as well as mosquito born diseases.

**Challenges in SDG-6**

Sanitation is a multidimensional problem including social, technical, financial and institutional challenges. Present pathway to improve sanitation is only limited on constructing the toilets with less focus on sustainability scale and without considering collecting excreta, transportation and its treatment. There is also low attention given to the sewer construction and water availability, advancement and improvement in waste management. Low political interference in service delivery, maintenance, human resource development, behavioral change, new knowledge creation, and unstructured national program is challenges of sustainability. This section systematically deals with challenges that may hamper the pathway to sustainable sanitation.
Societal challenges

Access and adoption of sanitation facility is mainly problem of poor population, who lives in urban slum and rural areas. India accounted largest number of population living below international poverty line in 2013, with 30 percent of its population living below poverty line on a $1.90-a per day (World Bank, 2012) and worsen the situation 0.15 percent population accounted 1.77 million are homeless (Cencus, 2011). Homeless people live on the street pavements, in hume-pipes, under fly-overs and staircases, or in the open in places of worship, mandaps, railway platforms etc. Poor and homeless people, who survive and cope by begging or some low wages job, for them main concern are food rather than use and build toilet or spend single penny for using toilet. The effects of poor socio-economic situation may seem obvious through unsanitary living condition. This raises a number of interesting questions about the SBM program or any other program with mandate to constructing infrastructure, how do these programs creates belief to use toilets for homeless or poor people, who suffer everyday for food
and water even, do not have permanent shelter? What are the different pathways to a SDGs-6 and Swatch India?

Socio-economic inequities in society are caused by the unequal distribution of power, income, goods and services, nationally and locally that determine people’s lives, homes, sanitary condition, their access to health care, schools, education and their conditions of work. Insanitary conditions caused social as well as biological disease, a psychological degradation that led desperate people to invest their hope in alcohol or worse (Hamlin, 1998). In India most marginalized communities engaged in manual scavenging. It is estimated that around 1.3 million marginalized castes in India, mostly women, make their living through manual scavenging. Manual scavenging term used to describe the job of removing human excrement from dry toilets and sewers using basic tools such as thin boards, buckets and baskets. Manual Scavengers are treated as untouchables and there is complete social exclusion. This practice is like a black spot on our society that was mainly invented by society itself. Manual scavengers face social, political and economic discrimination. Persons who refuse to do such type of work may face intense social pressure by higher caste group and are forced to do such work. They are exposed to certain health problems such as infectious disease, cardiovascular degeneration, and musculoskeletal disorders like osteoarthritis changes etc (Rashtriya Garima Abhiyan, 2013). Despite the government act to prohibit manual scavenging, it goes on and the funds allocated for rehabilitation are underutilized. The societal attitude towards the manual scavengers remains a challenge to improve sanitation and public health situation.

Cultural and Behavioral challenges

Sanitation is primarily a behavioral issue, despite having toilet at home rural Indian choose to defecate in open, even parents forcefully send their children to defecate in open. Water crisis did not allow people to use toilet built at home. People do not want to waste water for toilet use, which they collected from long distance or losing huge time. Some people do not use toilet because they felt suffocated inside in enclosed toilet and think go outside for defecation provides them an opportunity to take a morning walk, see their fields and take in the fresh air”. Some people do not construct latrine at home because they tend to view latrines as ritually impure and extremely concern about emptying pits. Some of the new toilets are being used as storerooms and animal shelter by people who consider toilets at home unhygienic (Kumar, 2010). Gender
disparities also play important role in open defecation, men think latrine use did not suite their daily life routine and open defecation may not shameful or lose dignity of them, latrine meant for female only as they need privacy and security. If females go outside to defecate, they stand up even in the middle of act, when someone passed but males do not stand up, because they think privacy is not required for them. Females also like to go for open defecation in the evening as they go in groups or in pairs in fields to chat with their friends/relatives about the ups and downs of their daily lives and to feel free from household chores. Females use this time as opportunities to chat with others and disconnect from household chores, relax, socialize, release their stress from family problems and for venting out (Routray et.al, 2015). In a village despite toilet constructed at home old men continue to go outside because they think “How can we go to the toilet that is also being used by our daughters-in-law?” If there are more members in family, toilet is used by just 30 percent of member mainly by female just due to fear about filling the tank, get dirty and utilization of much water. In some cases female also do not want to construct toilet at home because they fear of additional work load of keeping toilet clean as a woman who already spends much time in other household responsibilities.

In India, open defecation is not only behavioral problem but also a cultural issue. In our society, poor mentality of people did not allow using personal toilet by domestic worker, who sweep, mop, clean the floor, washroom and wash the dishes because they consider “unclean” or “low caste”. Domestic worker have to wait to answer nature’s call until they go home to use the toilet, or relieve themselves in the parks behind the plants. In India access to toilets for domestic workers remains a huge issue that created by the caste-system embedded in our society. Transgender people also behaved like social stigma and more often dissociated with the mainstream society and earn their bread and butter through blessings activities at the time of marriage and child birth. In India almost 5 lakh transgender people still facing everyday toilet challenges as there are few toilets are available for these people. Akkai Padmashali, a well-known trans-rights activist, one of the founder-members of Ondede, an organization that aims to create awareness about sexuality, sexual diversity and the third gender stated her story regarding ladies toilet use at Vidhana Soudha in Karnataka on “youth ki awaz ” an open platform.

7 https://www.youthkiawaaz.com/2016/12/domestic-workers-no-toilet-access/
Behavioral change of people’s habits of a lifetime is difficult, takes time and requires resources and skill with regards of adopting sanitation and hygiene practices such as the use of toilet, hand wash with soap, cooking practices. It is now understood that knowledge about germs is insufficient to change behavior due to financial costs, few technology choice as well as social attitudes to open defecation.

**Technological challenges**

Technology refers not only to product including infrastructures, but also to the knowledge, techniques and skills that surround its diffusion and use. Success of product technology innovation is dependent on its diffusion and adoption by society that may improve the way of livelihood (Tsinda et al, 2013; UN-Water, 2015). Sustainability in sanitation certainly cannot be guaranteed only by inducing technology and engineering, the technology feasibility, affordability and social acceptability always much greater than that availability of technology in the market. In case of sanitation technology, “one size fits all” model cannot fit and replicate all over so approaches need to be designed according to the need and concern of community, specific location, taking account of social aspects, tradition, geographical context, natural environment, institutional and financing arrangements. In rural and urban slum areas mostly toilet with septic tank has been constructed, once the tank is full, created concern to emptying it. There is no clear strategy for emptying of latrines, so full latrine develops risk of the overflowing, contaminating the environment with large quantities of excreta containing harmful pathogens and causing offensive smells and diseases (Connell, 2014, Coffey, 2014). Pit/septic toilets generally due to poor construction can collapse, hit bad smell after a period of use and can have serious health and environment consequences. Due to poor technology/engineering even newly fresh built toilet get chocked after few uses, that again forced to people adopt open defecation practices. In some villages where toilet constructed under national program, there is no proper running water supply, excreta deposable system so people get frustrated with the idea (Coffey, 2014). In India,

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there are only few toilets at few places available and accessible for disabled men and women. Toilet constructed for disabled people, many of these were found to be locked down or served as storehouses. Any national program has not shown much concern about the sanitation needs of persons with disabilities. India lacks sanitation technology considering disabled people. India cannot achieve Swatch Bharat Mission, until address the loop hole of flushing system of Indian railways, which fall excreta straight on to the tracks that open for humans to cross and come in contact with harmful bacteria responsible for spreading disease. Under the Swachh Rail-Swachh Bharat (Clean Rail-Clean India) programme, railways have planned to install bio-toilet a technology developed by Defence Research and Development Organisation (DRDO) in every train, 17,000 bio-toilets build in some trains and has plan to making up to 30,000 by 2019. Indian Railways has also installed vacuum toilets in few trains, at estimated cost Rs. 3 lakh. But it is still long way to go for sustainability as Indian railways generates more than 6000 tonnes solid waste from trains and passenger every day.

Sanitation is not just a rural problem in India, even in big cities; only 30 percent of sewage is treated and disposed of. According to the Centre for Science and Environment (CSE) 1.2 billion people in India generate 1.75 million tones of excreta per day in which only 22 percent of sewage is treated, while 78 percent is disposed of in open fields, rivers and lakes. Technology design in sanitation is very important for non-contamination as in many cases that discharge of chemical and microbial contaminants from pit/septic latrines to ground water may negatively affect human health (Graham & Polizzott, 2013). Prior toilet infrastructure and sewer construction engineer must look at the following important elements such as climate, water table, soil characteristics, and miserable distance from drinking water source etc., and then shall decide appropriate design of technology. In India very few studies focused on the above mentioned elements prior to constructing the toilet infrastructure. Sanitation technology must be focused on universal constant tap water supply, networks of high velocity sewers, safe disposal/treatment of sewage, recycling of solid wastes with technically proven engineering methods.

**Financial Challenges**

Since long run, low levels of government investment in sanitation and low political priority has been identified a biggest barriers to achieve universal sanitation in India. Until recently, urban

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sanitation has not been the main focus in most developing countries since the majority of the population lived in rural areas. However, the rapid growth of cities together with the growth of the urban poor and inequities created within cities, made urban slum sanitation status worst than rural (Gupta, Arnold & Lhungdim, and NFHS-3, 2005-2006). Though, poor sanitation and hygiene was identified as major sources of diseases and epidemics as way back in 1856 during British India, allotment of funds for the water supply and sanitation improvement was negligible. Which is less than 1.5% even after India became independent in its first to fifth five year Plans. Only in the sixth five year plan (1980 – 1985) amid the international decade for water supply and sanitation, the allocation was expanded to more than 4%. Urban water sanitation supplies (UWSS) were moderately higher over the rural area until the fifth five year Plan (1974-1979). However, since the Annual Plan of 1979-80 the rural water sanitation supply (RWSS) segment became the priority area for government expenditure [Figure-4], yet sanitation has not improved much in rural areas.

**Figure 4:** Increasing percent investment Rural Water-Sanitation supply and Urban Water-Sanitation supply (As percentage of total plan outlay)

*Source: Planning commission yearly report*
*Note: Outlays shown central plus state investment at current prices (2005-06)

Figure 5 indicates, water and sanitation sector expenditure of public funds which can have salubrious impact on both short as well as long term on health is lower as compared to the expenditure on nutrition and health care sector in India.

![Figure 5: Public expenditure on Health (curative), Nutrition and Water Supply, sanitation at per capita current price, Rs (2010-2011)](http://www.indiabudget.nic.in/es2012-13/estat1.pdf)


According Centre for Policy Research (CPR) report, the Government’s allocation for SBM-Gramin /rural increased three-and-half times, from 2,850 crore rupees in 2014-15 to ₹10,500 crore rupees in 2016-17. The budgeted allocation for 2017-18 is 13,948 crore, a 33 percent jump over the previous year (Kapur & Aggarwal, CPR, 2017) but its outcome indicators have also been disappointing. According to the SBM-G website, some 3.8 crore household toilets were built, which is about 63 percent of the mission target but the continuing open defecation and a high proportion of non-acceptability and poor maintenance, dysfunctional toilets, remain raised and challenges for the sustainability of sanitation and SDG-6 goals. It is important to make sure funds allocated under the National program spend in appropriate way to avoid fund crunch.

Institutional Challenges

There is lack of linkages and clarity on roles of different actors like government’s organisations, Community-based organisations (CBOs), Non-Governmental organisations (NGOs), municipalities, WHO and other external or internal agencies considering management of water and sanitation services. Within the state government and municipalities, sanitation has no ‘institutional home’, meaning that no single department or agency is accountable for it. As sanitation has multidimensional aspects such as infrastructure construction, selection of appropriate technology according to climate, soil, and community need, operation and maintenance of toilet, ensure water availability, electricity, sewer construction and waste water treatment plant that responsibilities assigned to different agencies and coordination between them is not always good. For example, if toilet constructed under national program but availability of water ensure water department and electricity by others and sewer construction by municipality. For instance, if state agency has developed sewage treatment plant even when there are no sewers in the town, then handed it over to a municipality that does not have the technical capacity or financial resources to operate and maintain it (Adil, 2013). Lack of community or end users involvement has led to the failure of program outcome. Such systemic weakness is barrier of achievement of successful outcome such as “Clean India”.

Lack of capacity is a major bottleneck that hinders progress in achieving access to sanitation. Capacity building is often refers in terms of staff training or human resources development. There is huge shortage of trained engineer, sanitary inspector, and sanitary worker in India. Municipality department should have one sanitary inspector to cover the population of 5,000 people. Since the positions were not filled for the past few years, now each sanitation inspector needs to cover at least 20,000 people. The increase work load has reduced efficiency of sanitary inspector and put the people at the risk of infectious and vector born disease. Social stigma being a mason and sanitation worker creates shortage of skilled mason that badly hitting infrastructure development and unskilled mason could not deliver sustainable toilet and sewer. The gap between demand and supply also increased the labor rate. For the sustainable access to technology required trained and scaled engineer that integrates efforts to make new technologies affordable, available where they are needed and facilitates adoption of the technologies within the systems (Galli, 2014; Niemeier et al, 2014). A number of factors affect human resource
development such as weak institution (rule/regulation), lack of financial support, and lack of familiarity with effective approaches to the sector (Rush & Marshall, 2015).

**Innovation System Framework for Sustainable Sanitation**

The ‘innovation system’ concept is an open, evolving and complex system encompassing relationships within and between individuals, institutions, socio-economic structures and organizations such as firms, consumers, public laboratories, universities, financial institutions and civic associations (Lundvall et.al, 2009). The innovation systems approach gives us an effective lens to view the systemic linkages and processes, to understand the global challenges in healthcare, water, energy, food and other social problems. The success of any national and international program towards addressing societal challenges depends on creation, diffusion, adoption and regulation of innovations (Edquist, 1997). Any commodity or asset is an innovation for a potential user who currently does not have access to one; the SBM and SDGs-6 can be viewed as a state programme to diffuse ‘toilets’ as an innovation (Ramani and SadreGhazi, 2014). If adoption and/or use of the innovation improve the quality of life of poor beneficiary significantly, then it is a pro-poor innovation. Sanitation is a typical example of a pro-poor innovation (Ramani et.al, 2016). In sanitation area innovation can come in all shape and size, for the poor segments it is about construction of affordable infrastructure and most important behavioral change towards adoption of infrastructure; sometimes it is about designing new products, other times it is about creating new business model. Sustainable sanitation cannot come only from technological innovation by just building toilets and bring technology it is more about social innovation by using toilet. Technology innovation won’t be successful without strong social innovation. Without a stronger emphasis on social innovation, a lot of the investments made in the development of technological innovations may be waste of time and resources. Total sanitation campaign has been launched in 1999 with aim to make India open defecation free but failed to translate into practice and outcomes were remarkably poor because social innovation could not emphasized. “Availability” and “acceptability” are two main drivers of technological innovation diffusion (Reddy 1991; Tilley et al, 2006.). In India 88 percent household have mobile phone while 54 percent have toilet within their home. Mobile phone beats toilet at all level because wide range of availability in respect of cost and design, instant outcome such as communication, entertainment etc., and awareness by high advertisement, & social mobilization.
In case of sanitation technological availability need additional efforts i.e; motivate user “accept it”, realize the need of toilet as desperately as they need of mobile by social innovation that come by change their behavior away from open defecation.

**Pathways to sustainable sanitation**

Sustainable sanitation requires the integration of social, environmental, technical, financial and institutional sustainability. This section attempts to designs a theoretical framework to represent pathway of sustainability and answer the challenges of sustainable sanitation with the lens of innovation system.

![Figure 6: Pathways to sustainable sanitation](image)

**Social Innovation**

Social innovation is a broader term but precise and universally accepted definition is still missing (Franz, Hochgerner & Howaldt, 2012). Social innovation defines a “catch all” category for all other form of innovation including improvement in the process or delivery of a technology as well as improved organizational and institutional arrangements (Hanlin, 2016). A social innovation is a new combination or new configuration of social practices in certain areas of action or social contexts driven by certain actors in targeted manner with the goal of better satisfying needs and problems that is possible on the basis of established practices (Howaldt, Schwarz Kopp &, 2013). Social innovation is mainly a new idea (knowledge, model, process) that answered societal challenges and meet societal need to improve quality of life of society (Anderson, Curtis & Wittig, 2014). In case of sanitation, social innovation is more about to create willingness to adopt sanitation at household level. One of the main problems in adoption of sanitation is lack of communication as the discussion of toilet feels dirty and impure and is associated with the negative stigma in society. Behavioral change through communication campaign, information education and communication (IEC) method, systematic advocacy and audio-visual aids, display of photographs/cartoon related to personal and community hygiene,
Street plays with the script composed in folk local language related to sanitation and hygiene practices may sensitize community at the regional, local and national level. Sanitation and hygiene promotion must be designed geographically, regionally and aimed to create awareness among diverse and specific mindset of people spread over the different socio-cultural system. Sanitation behavioral practices determinants are benefits, beliefs and threats. Public beliefs must be gained through regular, transparent, and comprehensive communications with local community that balance the risks and benefits of sanitation. Household adoption of sanitation practices is often associated with comfort, save time, prestige, social dignity and safety as much as with health considerations. Inclusion of some incentive schemes and awards (family planning in India has cash prize incentives) may be important determinants for changing socio-cultural system and adopt sanitation measure that gets integrated into their culture. Behavioral sustainability may achieved by also improving socio-economic condition to reduce poverty, focused on marginalized and under deprived population, changing power, caste and class relationship within society as well as community and service providers, knowledge creation at local and national level and strengthening capacity building at local and state level. Once the behavior change has been adopted by a critical mass of people, it becomes self-sustaining (Curtis, 2005). Behavior and cultural transformation is a cost-effective and bottom up approach, which makes it highly scalable.
Knowledge creation and development

In Innovation system, knowledge creation relates to the competence building that produce by formal/informal training, workshop, conferences and high education and knowledge flows by publications, documents, and reports. Measures of research activities are based on fractionalized publication by different actors and national or international and public or private organizations. Publication activities on sanitation based research of two decades during the period 1996-2016 by Indian organizations consisting public sector and private sector institutions bring out only 566 publications in science citation-index (SCI) journal indicates rising pattern with little up-down while significant work in the area of sanitation research has started after 2006 mainly by public sector institute(figure-7). Figure 7 shows that contribution of research institutes is less than medical colleges and academia while international organizations also have significant contributions with collaborating Indian organizations. Although the volume of knowledge produced in terms of publication activities is not very significant, need more publication by research institutes and other actors such as NGOs to facilitate the sustainable sanitation challenges by new ideas and policy.
Technological Innovation:

Technological innovation is essential to solving many of the problems surrounding global poverty. Technological innovation can be made through capacity and capability building, education and institutional reform. In case of sanitation, affordable, low water consuming, sustainable, easy operative, less maintenance, easy installable and availability of wide number of technology is most important to solve the sanitation crisis. Technology needs to be innovated carefully, with proper reference to regional and local conditions, the availability of other resources such as water, space and the needs and preferences of service users.

Technology used in India:

- **E-toilet**: Eram Scientific Solutions Company developed a coin-operated eToilet with an electronic system that automatically cleans itself after each use and the water gets recycled for flushing. In India 500 e-toilets are now in use which includes 150 in schools.
This type of toilet need technician visit for periodic inspections to ensure sustainability of toilet\(^ {11}\).

- **GARV toilet**: Mayank Midha invented comprehensive and sustainable stainless steel insulated GARV Toilet. GRAV toilets are vandal-proof, easy to clean and they don’t rust. When users exit, technology can automatically activate floor washing and toilet pan washing systems\(^ {12}\).

- **Eco-friendly Two Pit, Pour-Flush Compost Toilet**: Dr Bhindeshwar Pathak owner of Sulabh toilet, two pit model is very simple and installed in individual households. This toilet technology has also been recommended as a Best Global practice by the UN\(^ {13}\).

- **RCC Affordable Toilet Technology**: Ramdas Mansing Mane invented an excellent quality of ready-made portable toilets by using scrape Expanded Polystyrene (EPS)/Thermocol sandwiched with concrete to reduce the weight and price of toilet which can be installed within two hours and with half of the price\(^ {14}\).

- **EcoSan Model**: The basic concept of Ecological Sanitation model is to manage human excreta and urine by decomposing them before deposing, into useful organic resources, which can be handled safely and used in agriculture without harming environment\(^ {15}\).

- **Bio-gas linked toilet**: This toilet model convert waste material to Bio-gas, a non-conventional energy source. The fuel generated can be used as local source for electricity, heat and light and the waste can be composted to Bio-manure which increases productivity and catalyses soil conservation. In 2012, UNICEF chose two districts in West Bengal to pilot this kind of design in India\(^ {16}\).

- **Precast Textile Reinforced Concrete (TRC) based Toilet**: Life Long Textile Reinforced Concrete (TRC) based Smart Toilet for Rural India Toilet is developed by state of art technology. it can be colored with fire, corrosion and UV degradation resistant, no maintenance for lifelong usage.

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\(^{16}\) [http://www.thealternative.in/business/10-toilet-designs-for-rural-india/](http://www.thealternative.in/business/10-toilet-designs-for-rural-india/)
• **Bio-toilets:** In India bio-toilet are installing in railways, in this technology anaerobic bacteria is used for de-composition of fecal matter in to gas and water. Sulabhb has designed an open roof toilet to incentivize men who feel claustrophobic in the confines of a toilet, although it is not clear how this will work in bitter winters or monsoons. Now these above mentioned innovative sanitation technology needs to be promoted, commercialised and utilized correctly to full fill societal needs and bring sustainable sanitation.

![Figure 9: Theoretical innovation framework for sustainable sanitation](image)

**Financial Inclusion**

Financial inclusion in the sanitation must be providing funds for all the elements for sanitation program. Apart from infrastructure development, public and private fund must be used for to create awareness, capacity building, hygiene practices, and community hardware such as drainage, sewer constructions, waste transportation facility, waste treatment plant, monitoring system, policy development and institutional strengthening. Human resources for behavior change and trained mason and qualified engineer are equally important. A rough estimate shows
about 6.4 lakh trained people will be needed from panchayat to state levels to run “Swatch Bharat Mission”. The maximum strength of 600,000 is at the village level (one person per village) followed by about 33,000 at the block level, 3,265 at the district and 175 at the state level\textsuperscript{17}.

Although government is paying attention to eliminate open defecation and improving waste management service to make “Clean India” but funds allocated these are only about 30% of the envisaged requirement. Thus, there is a clear need to facilitate innovative financing mechanisms by integrated financial model consisting micro-financing, Housing finance institution commercial bank loans, corporate social responsibility (CSR) and crowd funding align with local government financing. In India, Guardian and Grameen Koota are working as micro –financing institution in the area of water and sanitation. Guardian works in four district in Tamil Nadu and accepted loan over 11 crore and Grameen koott also doing incredible job in Karnataka, Maharashtra and Tamil Nadu, crossed a disbursement of Rs. 100 crore. Crowd funding is a new financing mechanism, at nascent stage in India mobilises fund through internet platform from large number of people. Globally Indiegogo, Spacehive, Akvo and Kiva are working and in India only few such as Milaap and BitGiving mobilise loans for water and sanitation\textsuperscript{18} (Mehta & Mehta, 2014). Commercial bank and CSR fund may become largest source of funding for sanitation in rural as well as urban also. But there is also need to facilitate, advertise, promote and create awareness of these innovative financing schemes to reach the most vulnerable and marginalized people. These financial schemes must have easily accessible and available process so that people can get benefited. There are several national programs such as Pradhan Mantri Gramin Yojana for constructing house in rural and Janani Suraksha to improve institutional delivery for pregnant women could not benefitted the people due to complicated mechanism. There is some program and international funding agency actively supports and ensures consistency with the Government of India’s ‘Swachh Bharat’ (‘Clean India’) campaign, such as Water Supply and Sanitation Collaborative council (WSSCC), Bill & Melinda Gates Foundation, World Health Organization (WHO),UNICEF, United States Agency for International Development (USAID), Arghyam Foundation, Paul Hamlyn Foundation, The Coca-Cola India Foundation, Bharti Foundation, Hindustan Unilever, Tata motors, Dabur, A

\textsuperscript{17} http://www.thehindubusinessline.com/opinion/financing-swachh-bharat/article7089855.ece
\textsuperscript{18} http://www.ideasforindia.in/article.aspx?article_id=370
Maruti Suzuki etc.. Apart from Government some others public and private companies also boosting clean drive of India by constructing infrastructure.

**Table 2:** List of top companies boosting “Clean India” drive.

<table>
<thead>
<tr>
<th>Company/Corporate</th>
<th>No. of Toilet completed/Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal India</td>
<td>51,115</td>
</tr>
<tr>
<td>National Thermal Power Corporation Limited (NTPC)</td>
<td>24,626</td>
</tr>
<tr>
<td>Rural Electrification Corporation (REC)</td>
<td>12,379</td>
</tr>
<tr>
<td>Power Finance Corporation (PFC)</td>
<td>9,026</td>
</tr>
<tr>
<td>Vedanta Resources</td>
<td>9000</td>
</tr>
<tr>
<td>Oil and Natural Gas Corporation Limited (ONGC)</td>
<td>7,958</td>
</tr>
<tr>
<td>Tata Consultancy Services (TCS)</td>
<td>1,509</td>
</tr>
<tr>
<td>Mahindra</td>
<td>1,179</td>
</tr>
<tr>
<td>Airports Authority of India (AAI)</td>
<td>765</td>
</tr>
<tr>
<td>IFIG</td>
<td>150</td>
</tr>
<tr>
<td>Confederation of Indian Industry (CII)</td>
<td>138</td>
</tr>
<tr>
<td>GAIL (Proposed)</td>
<td>1021</td>
</tr>
<tr>
<td>Bharti Foundation (Proposed)</td>
<td>30,000</td>
</tr>
<tr>
<td>L&amp;T (Proposed)</td>
<td>5,000</td>
</tr>
</tbody>
</table>


**Organisational innovation**

Organisational innovation in the sanitation sector is not only about the coming together of private firm or private firm with public entities. There is also a wider set of inter-organistaional innovation such as water, health and environmental sector have been taking place and that are promoted to create more effective, sustainable output. The engagement of all actors along with societal actors mainly community, civil society and end users into research and innovation process shall help to achieve sustainable goal. Actors typically include individuals and organizations operating at multiple scales such as central governments, local authorities, panchayat, ward, universities, private firms, nonprofits organization, policy makers, entrepreneurs, and technology users. The grand societal challenges may be far better tackled if all societal actors are fully engaged in the construction of innovative solutions, products and services (Owen et al, 2012). Decision making on sanitation policy must tend to be conducted at a central government level, involving municipal department, local government worker and gram panchayat. Nongovernment organizations should be encouraged to participate in sanitation drive
with induction of public-private partnership (PPP) model. At present, while policy makers and scholars recognize that social entrepreneurship has a crucial role to play as an innovation carrier in the area of sanitation because sanitation is a mainly social problem (Ramani et al, 2016). Social enterprises view “social problems” as “opportunities” and struggle to create social impact through create awareness by developing an emotional connection with the targeted consumers via life-quality enhancing activities and project (Sridharan & Viswanathan, 2008). Social enterprises act like a catalyst for sustainable development mainly focused on adoption of technology effectively in community.

Community participation is very important to understand their existing traditions, cultures, divisions, and structures for sustainable result. Involvement of women in sanitation camping may lead to better and fast adoption pace. For example, Bangladesh has developed a successful model to adopt community-led total sanitation approach to stop open defecation (Ahmad, 2008) and woman’s energetic involvement in sanitation campaigns provide sustainable solution as women are much more interested in toilet than men (Hanchett, 2016). In India “Midanpore model” has became one of the biggest success stories and cited all over the world for sustainable alternative delivery system for sanitation. In India the west Bengal’s a Midanpore was declared the 1st district in the country to have 100 percent access to sanitation toilet in 2001. The success of the Midanpore model based on excellent network system that connects program authorities to community and end users and maintenance of low cost sanitation hardware that made the system viable and affordable to the end user. (Banerjee & Mandal, 2011). India needs to review all successful models and try to replicate considering different socio-cultural regime. Public-private partnership (PPP) model also plays an important role in bringing sustainability in water and sanitation area. In the China sustainable sanitation and water is the best example of PPPs that emerged as one of the most active market in the world for PPPs in water and sanitation (Wu el al, 2016). In India involvement of private sector is limited to technical and management support rather than investment in infrastructure. In India, Nagpur is the first city to adopt PPP model for city wide water supply (NIUA, 2015). Garv Stainless Steel Public Toilet Infrastructure set up PPPs with municipal corporations for installation, operation and maintenance of toilets primarily in some cities. In recent years, Non-profit organization namely Sulabh International, Finish Society, Shuddhi, SPARC, Arghyam, Niwas etc. actively participated in sanitation drive in rural
and urban areas that may help to accelerate “Swatch Bharat Mission” and Sustainable Development Goal-6.

**Table 3:** List of NGO/Trust/Social organization (Non-Profit organization) undertaking CSR projects in the field of rural drinking water and sanitation under Ministry of drinking water and sanitation

<table>
<thead>
<tr>
<th>Name of Non-profit Organization</th>
<th>Specialization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulabh International Social Service Organization</td>
<td>Implementation of sanitation project/infrastructure</td>
</tr>
<tr>
<td>Plan India</td>
<td>Implementation of Water and sanitation project/Practices</td>
</tr>
<tr>
<td>BAF Development Research</td>
<td>Watershed management/ Sustainability Structures</td>
</tr>
<tr>
<td>Himalayan institute hospital trust</td>
<td>Implementation of Drinking Water Supply</td>
</tr>
<tr>
<td>Bhoruka charitable trust</td>
<td>IEC and Capacity Building</td>
</tr>
<tr>
<td>Gram Vikas</td>
<td>Implementation of Water and Sanitation</td>
</tr>
<tr>
<td>BYPASS Sansthan</td>
<td>Implementation of Drinking Water</td>
</tr>
<tr>
<td>Gramin Vikas Trust</td>
<td>Implementation of Sanitation project</td>
</tr>
<tr>
<td>The Energy and Resources Institute</td>
<td>Capacity building/ M&amp;E</td>
</tr>
<tr>
<td>Support for Implement and Research(SIR)</td>
<td>Water and sanitation project</td>
</tr>
<tr>
<td>Centre for environment education</td>
<td>Implementation of Sanitation Project</td>
</tr>
<tr>
<td>Arpan Sewa Snasthan</td>
<td>Training and capacity Building</td>
</tr>
<tr>
<td>Socio-economic unit foundation</td>
<td>Implementation of water treatment plant</td>
</tr>
<tr>
<td>Manthan Gramin evam Samaj Sewa Samiti</td>
<td>Implementation of solid waste water management</td>
</tr>
<tr>
<td>M.R.Moraka,Rural Resaerch Foundation</td>
<td>Implementation of waste water management</td>
</tr>
<tr>
<td>Citizens Foundation</td>
<td>Community development, water harvesting</td>
</tr>
<tr>
<td>Tulsi Shiksha Samiti</td>
<td>IEC campaign and capacity building in water and sanitation</td>
</tr>
<tr>
<td>Staya Foundation</td>
<td>M &amp; E implementation of water quality and community building</td>
</tr>
<tr>
<td>Aga Khan Rural Support Programme</td>
<td>Implementation of water and Sanitation Project</td>
</tr>
<tr>
<td>Ambuja Cement Foundations</td>
<td>Implementation of water and Sanitation Project</td>
</tr>
<tr>
<td>Developments Alternatives</td>
<td>Implementation of water Projects</td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Administrative staff college</td>
<td>Capacity building and project foundation</td>
</tr>
<tr>
<td>Humana people to people India</td>
<td>Eco-san toilet</td>
</tr>
<tr>
<td>Nirmal foundation</td>
<td>Implementation of rain water harvesting and water Projects</td>
</tr>
<tr>
<td>Self Development Institute</td>
<td>Capacity Building</td>
</tr>
<tr>
<td>International Academy of Environmental Sanitation and Public Health</td>
<td>Implementation of water and Sanitation Project</td>
</tr>
<tr>
<td>M.G.S.A resource centre</td>
<td>Awareness program in sanitation</td>
</tr>
<tr>
<td>Indian Grameen Services</td>
<td>Capacity Building</td>
</tr>
<tr>
<td>Keshari Chand Puran Chnad Sethi Charitable Trust</td>
<td>Implementation of water and Sanitation Project</td>
</tr>
<tr>
<td>ACII</td>
<td>Implementation of water and Sanitation Project</td>
</tr>
<tr>
<td>Ashwamwegh Gramin Panlot kshetra Vikas</td>
<td>Implementation of water and Sanitation Project</td>
</tr>
<tr>
<td>AFPRO</td>
<td>Capacity Building in water and sanitation</td>
</tr>
</tbody>
</table>

Source: Website of MDWS. Available at: [http://www.mdws.gov.in](http://www.mdws.gov.in)

**Policy and Institutions**

Several government initiatives in the form of schemes and programs have launched from time to time to improve sanitation situation in India. It started from launching of central rural sanitation program in 1986 with an objective to accelerate sanitation coverage in rural areas. This includes total Sanitation Campaign (1999) to improve sanitation coverage by motivating communities and Panchayati Raj Institutions; Nirmal Bhart Abhiyan (2007) to make India clean and healthy; and the latest Swatch Bharat Mission (2014) to eliminate open defecation by 2019. Effective translation of national program into sustainable development is facing many challenges due to various uncertainties associated with weak institutions and management. Institutions include the set of formal and informal rules, norms, decision-making procedures, beliefs, incentives, and expectations that guide the relations and performance of actors in an innovation system (March, 2006; Johnson, 2010). Institutions govern complex adaptive system involving different actors and organizations operating simultaneously from local to global scales to deal with challenges and facilitate sustainable development (Lundvall, 2010). As per the Constitution of India, water and sanitation is a responsibility of the State Governments that assisted by the central government. The States have generally delegated powers to the local bodies for provision of these services to
people at the local level. The intergovernmental transfer of fund or multistage governing body between central to state and then state to local bodies and weak network and linkages among these actors may affect and delay the outputs of program (Bharat & Sarkar, 2016). Government funding towards improving sanitation should be distributed at the different stage carefully to evaluate the strong driver, need and gap at different elements of sanitation. For example lack of adequate capacity, especially at the municipal levels, inadequate local knowledge, low community involvement and poor monitoring adversely affected the implementation of the program in many ways. There is need to create and strengthen appropriate network and linkages and knowledge at the local level that are responsible, efficient, and accountable and capable of providing quality services. There is also need to focus on component of sanitation system such as use of toilet then safe excreta collection followed by transport, treatment and disposal at local level.

**Conclusion and Discussion**

Sustainable development goal-6 to “ensure availability and sustainable management of water and sanitation for all” can be achieved by following suitable pathway and integrating sustainability through social, technological, financial and institutional innovation. Sanitation is primarily a social problem cannot be solved just by “building toilet” and it is about “adopting” and “using” the technology with stronger emphasis for sustainability. Sustainability in technological innovation can be shaped by providing focus on some important factor such as availability of wide range, affordability, easily operative, low maintenance, eco-friendly and implementation of technology with proper reference to regional and local condition talking account of socio-economic, cultural and traditional context and the availability of other resources such as water, hand wash facility, space and the needs and preferences of service users. Strengthening capacity building at local level by training of mason, engineer, sanitary worker, increase number of sanitary inspector and inclusion of women and local community in sanitation camping can boost sustainable pathway. Technological innovations in reuse/or recycling of human waste and financial support as an incentive for solid waste management at local level ensures sustainability. Such institutional mechanisms stimulate sustainable economic development by offering incentives for business development and employment creation. Further, it requires the creation and strengthening appropriate network, linkages and knowledge at the local level that are responsible, efficient, accountable and capable of providing quality services. There is also need
to focus on components of sanitation system such as use of toilet then safe excreta collection followed by transport, treatment and disposal at local level. Financial inclusion should be carefully distributed to the every elements of sanitation such as capacity building, waste management and monitoring to ensure the benefit to the most vulnerable and marginalized people and communities. Human waste can be turned into high quality products, such as nutrients, biogas and organic fertilizers.

Social innovation to bring behavioral changes and attitudes of communities is possible through continuous advocacy, knowledge creation, motivation, mobilization, and sensitization and awareness activities to implement sustainable sanitation in the society. Structural rigidities that are present in the society such as caste, social class, gender disparities, power, prestige, beliefs, superstitions etc., can be combated by consistent and continuous advocacy to sensitize the masses/communities particularly on the deleterious effects of lack of sanitation on their children health, women dignity, pride and privacy etc. to bring the mass transformation of mindset slowly and consistently. Successful models such as Sikkim and Manipur can be adopted in other states as well. More involvement of NGO and launching more social campaigns by state government like ‘no toilet, no bride’ resolution taken by Haryana government and facilitated by panchayat may bring sustainable solution.

Innovation in sanitation is a bottom up approach that requires both macro and micro management of systematic planning and strategy involving all stake-holders by building strong cross-sectoral linkages and network among national and international actors and organizations. Enterprises can play more proactive role in the maintenance of infrastructure as through their commitment to social responsibility. NGOs and corporate companies can play a facilitator role in clean India drive through their active participation in promotional activities such as demand creation, mass mobilization/sensitization, capacity building and maintenance of technology rather than building of only infrastructure.

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