

Why China Needs the “Toilet Revolution”?

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Abstract

The wide-spread prevalence of unimproved sanitation technologies has been a major cause of concern for the environment and public health, China is no exception. Towards sanitation issue, toilet revolution becomes a buzzword in China recently. This paper elaborates the backgrounds, connotations, actions of toilet revolution in China. Toilet revolution requires to create sanitation infrastructure and public services that work for everyone and that keep waste out of the environment. Opportunities for implementing toilet revolution include fulfilling Millennium Development Goals and Sustainable Development Goals, government support at all levels for popularizing sanitary toilet, environmental protection to alleviate wastewater pollution and resources recovery from human waste, diseases prevention for health improvement and poverty alleviation for wellbeing. Meanwhile, challenges faced are emphasized, which come down to: insufficient fund and policy support, region imbalance and lagging approval process, weak sanitary awareness and low acceptance of new toilets, lack of R&D and service system. For the future work, revolution toilet requires concerted effort from many department. It needs to address not only technology implementation but also social acceptance, economic affordability, maintenance issues and, increasingly, gender considerations. Aligned with the ecological sanitation principles, it requires understanding issues across the entire sanitation service chain. Public-private partnership is also recommended to absorb private capital to make up the lack of funds, as well as arouse the enthusiasm of the public.

Keywords

toilet revolution; sanitation; challenge; China

INTRODUCTIONS – WHAT’S BEHIND?

By 2015, one in three people (2.4 billion) in the world still use unimproved sanitation facilities, including 946 million people who still practise open defecation, and the consequences can be devastating for human health as well as the environment. Even in urban areas, where household and communal toilets are more prevalent, over 2 billion people use toilets connected to septic tanks that are not safely emptied or use other systems that discharge raw sewage into open drains or surface waters. Today over 880 million people are estimated to be living in slum-like conditions in the developing world’s cities. About 50 per cent of people living in rural areas lack improved sanitation facilities, compared to only 18 per cent of people in urban areas (UNICEF/WHO, 2014; UNICEF/WHO, 2015; MFA and UN, 2015). Poor sanitation around the world results in increased prevalence of diseases and pollution of the environment. Excreta, grey water and solid wastes are the major contributors to the pollution load into the environment and pose a risk to public health (Katukiza et al, 2012). Public agencies often grapple with the question why the adoption of improved sanitation technologies has been slow (Seleman & Bhat, 2016).

When it comes to China, the scenario is not optimistic, neither, although China had made great progress in the past decades. According to data of the 2014 country reports of the joint monitoring programme by UNICEF/WHO for water supply and sanitation, in 2012, 98% of urban population in China had access to improved toilets. The coverage of sanitary toilets in Chinese rural areas

increased from 7.5% in 1993 to 74.1% in 2013. In the central and western parts of China, in particular, basic sanitary conditions in rural areas have been markedly improved, effectively containing the breakout and spread of diseases. The health, environmental, economic, and social benefits of improved toilets have been gradually demonstrated, winning high acclaim from the public and the international community. Table 1 shows the changes of sanitation facility in different time nodes.

Table 1. Percentage of sanitation facility in China

Year	Population in billion	% urban population	Urban				Rural			
			Improved	Unimproved			Improved	Unimproved		
				Shared	Other unimproved	Open defecation		Shared	Other unimproved	Open defecation
1990	1.165	26	48	15	34	3	15	4	72	9
2000	1.280	36	61	20	18	1	35	9	51	5
2012	1.377	52	74	24	2	0	56	14	28	2
2015	1.402	56	87	6	7	0	64	3	31	2

Source: Adapted from Progress on Sanitation and Drinking Water 2014 and 2015 by UNICEF/WHO

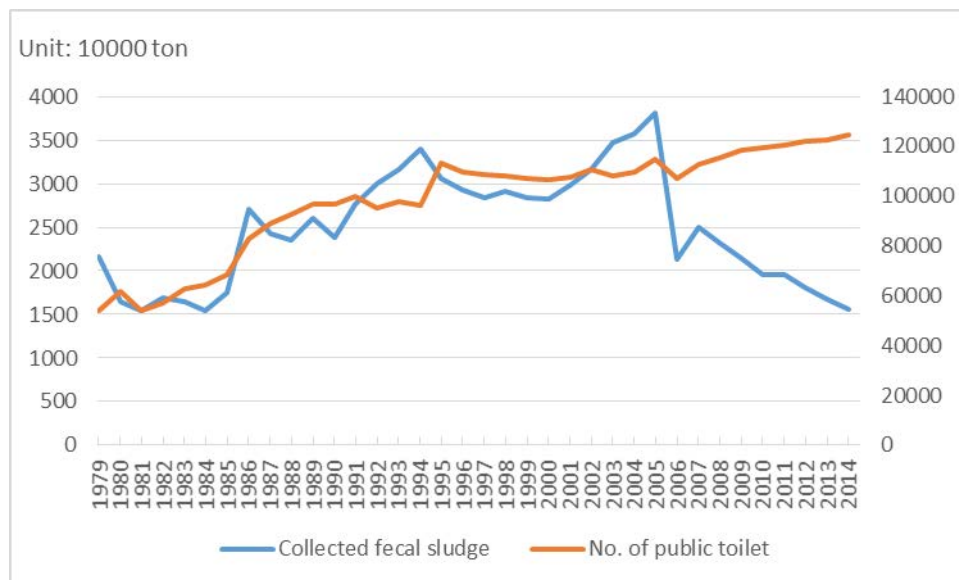


Figure 1. Collected faecal sludge and quantity of public toilet in urban areas (MOHURD, 2015)

In light of urban sanitation, in 2014, the collection amount of urban faecal sludge is 15.46 million ton, among, 6.91 million ton is treated while the treatment ratio is 44.7%. Of all provinces and municipalities, Beijing led the nation, in terms that the treatment ratio of faecal sludge can reach 91.4%. Figure 1 shows the trend of collected faecal sludge and quantity of public toilet in urban China. It is observed that the amount of faecal sludge is decreasing in the past decade. The reason may come down to the more distribution of municipal pipeline which can collect more human faeces into wastewater treatment plant via municipal pipe. Another reason would be that government contracts with more private for collection and handling faecal sludge, while only faecal

sludge in scope of governmental responsibility is taken into statistics. However, this doesn't mean that the actual faecal sludge amount and its potential damage to environment is reducing.

WHAT IS GOING? – TOILET ACTION

When foreigners visit China tourist areas, they complain the issue of public toilet most. Many foreigners said they will never forget the scary toilet experience. Given this fact, how can our tourism industry take big strides? Then toilet revolution came into being in tourism sector firstly. China National Tourism Administration (NTA) set the target that from 2015 to 2017, 25000 public toilets will be expanded built and another 33500 will be newly built in tourist areas within 3 years, which is also known as Three-year Toilet Plan. Clean and standard toilet will be a key index for evaluating tourism areas.

“Toilet Revolution” became a hot word in 2015 in China. On 1st of April, 2015, President Xi Jinping specially made important comments on toilet revolution and civilized tourism. In addition, when he investigated in Jilin Province on 16th of July, 2016, he saw some farmers still used traditional latrine pit. He said our rural areas will also launch a “toilet revolution” to let farmers use sanitary toilet. When we talked about toilet in rural China, there would be two barriers, one is bad odour, the other is hidden sanitary trouble. Actually, toilet revolution is tightly associated with the patriotic health campaign, which first started in the 1950s.

Internationally, in 2011, Bill & Melinda Gates Foundation (BMGF) initiated the Reinvent the Toilet Challenge (RTTC) to bring sustainable sanitation solutions to the 2.5 billion people worldwide who don't have access to safe, affordable sanitation. Grants have been awarded to sixteen researchers around the world who are using innovative approaches—based on fundamental engineering processes—for the safe and sustainable management of human waste. In addition to these RTTC grants, BMGF has made a range of other investments that are aligned with reinventing the toilet, and we are continuously seeking to expand our partnerships on this challenge. In August 2013, the foundation announced the Reinvent the Toilet Challenge: China (BMGF, 2016). The foundation will invest US\$5 million to support Chinese investigators to drive research, development, and production of the “next generation toilet.” This China toilet challenge is the first effort targeted to a specific country and is a testament to the research and development capabilities in China. The funded proposals after selection are presented in Table 2.

Table 2. Funded proposals for Reinvent the Toilet Challenge-China

	Proposal description	Lead Applicant	Nature of entity
1	Novel faeces and urine resource-oriented treatment system focusing on forward osmosis technology	Tsinghua University	University
2	Bio-oil production system from human faeces based on source separation	Beijing University of Chemical Technology	University
3	System construction and operation optimization for black water treatment by combination of efficient MFC-MEC-ABR	University of Shanghai for Science and Technology	University
4	Human faeces and urine environment-enhancing system and device by combination of thermal hydrolysis and gasification	China Agricultural University	University
5	Human waste treatment and nutrient and electricity energy recovery based on magnesium ammonium phosphate (MAP) crystallization and microbial desalination cell technology	China university of Geosciences (Beijing)	University

6	Air flushing toilet system	Beijing EnviroSystems Engineering and Technology Co.,Ltd	Company
7	Anhydrous self-cleaning transmission type source separation device with biological bacterium and deodorization system	Hunan Environment Biological Technology Co.,Ltd	Hyso Company
8	R & D on biodegradable foaming solution for specialized bubble toilet	Kunming Luminous Engineering Co., Ltd.	Huiyun Company
9	R & D on microbial agent for faeces from waterless flushing toilet or micro-water flushing toilet	Dalian Jinzhou Jinshui Cleaning Facilities Factory	Company

Domestically, NTA launched 1st National Tourism Toilet Design Competition in 2015. Again in January of 2016, together with BMGF, NTA launched 1st National Toilet Technical Innovation Competition, in order to response the “Toilet Revolution” and speed up the progress.

China has incorporated toilet renovation in rural areas into major national public health projects. Starting from the 1990’s, China began to incorporate toilet renovation into the outline programme for children’s development and health reform and development. Since then, a “toilet revolution” has occurred in the vast rural areas, with sustained input increase. Since 2004, the central government has earmarked RMB 8.64 billion which renovated 21.03 million rural toilets. In the Key Implementation Plans on the Reforms of the Medical and Health Care System in Recent Period (2009-2011) formulated by the Chinese government, rural toilet renovation has been incorporated into key national public health projects. The goal for rural toilet renovation in China is to reach the 85% penetration rate of sanitary toilets in China’s rural areas by 2020. In 2015, National Patriotic Health Campaign Committee (NPHCC) launched National Urban and Rural Sanitation Action Plan (2015-2020) (NPHCC, 2015). Rural toilet renovation will be speeded up. It is encourage to construct four-chamber eco-toilet and biogas digester, and thereby strengthen the harmless use and resource-oriented use of human faeces. New-built housing and government-subsidized housing in rural areas should be attached to harmless sanitary toilet. Public sanitary toilet should be popularized at township government building, primary and middle school, health clinics in towns and townships, rural community integrated service station, pedlars' market, tourist attraction, highway roadside, etc. Health education should be highlighted. Farmers should be guided to use sanitary toilet, and the long-effect management mechanism should be formed on build-maintenance-use of sanitary toilet.

WHAT’S TOILET REVOLUTION?

Whether you call it the loo, john, privy, lavatory or toilet, this facility is essential wherever humans gather or live: toilet provision has even been called the barometer of civilisation (Stanwell-Smith, 2010). However, toilet, always, is treated as a matter of taboo, especially for any form of latrines, while flush toilets are considered prestigious and desirable. There is no explicit literature report on origin of toilet revolution in China. The fact is that China is had suffered a lot since the foundation of People’s Republic in 1949 from infectious disease, which results from open defecation and poor sanitation. In 1960s, China started national patriotic health campaign, aiming at building new toilet, managing faecal sludge and preventing environmental pollution. To some extent, this can be treated as the start-up of Chinese toilet revolution.

Actually, the word “toilet revolution” was proposed first by UNICEF, it referred in particular to toilet retrofitting in developing countries, following the sanitation target under MDGs. Until NTA launched tourism toilet revolution recently, the world “toilet revolution” was reported a lot by means of news and media, especially, after President Xi Jinping mentioned “toilet revolution” in his speech when he inspected rural areas.

Currently, the concept of toilet revolution is enlarged and extended. It happens in many sector, for instance, the toilet retrofitting in rural areas, the public toilet in tourist areas, the public toilet in highway resting areas, the reinvented toilet in R & D, etc. Moreover, it is not confined to the toilet itself, instead, a whole sanitary system. A sanitation system – contrary to a sanitation technology – considers all components required for the adequate management of human wastes, such as storage, collection, transport, treatment, discharge or reuse at these levels (Zurbrugg & Tilley, 2009). Starting at the household level with waste generation, a system can include storage and potentially also treatment and reuse of all products such as urine, excreta, greywater, rainwater/stormwater or even solid waste. However, problems can rarely be solved at the household level alone. The household “exports” waste to the neighbourhood, town, or downstream population. In such cases, it is crucial that the sanitation system boundary be extended to include these larger spatial sections.

Look back, the concept of toilet revolution is somehow equal to the concept of ecological sanitation (Eco-San) (Winblad and Simpson-Hébert, 2004; Hu et al, 2016). The term ‘Eco-San’ appeared in 1990’s (Esrey et al., 1998), and quickly got a shot at stardom of the new millennium concepts. The UN issued a declaration of ‘Eco-San-closing the loop in wastewater management and sanitation’ in 2000 (Winblad, 2004). The Eco-San system is an alternative approach to realize sustainable sanitation, which is closely associated with toilet. It is known as the resources-oriented sanitation and based on ecosystem approaches, the closure of material flow cycles, a novel trend of pollution treatment (from sewage disposal to resources reclamation), and a re-conceptualization of sanitation (from a ‘drop-flush-forget’ mode to environment protection at sources by means of ‘drop and reuse’ mode) (Haq and Cambridge, 2012; Langergraber and Muellegger, 2005). It can be seen that toilet revolution, in the view of Eco-San, is dedicated in optimizing cost efficiency, resource reuse and waste disposal (Werner et al., 2009).

OPPORTUNITIES FOR IMPLEMENTING TOILET REVOLUTION

China owns the biggest toilet market in the world, some factors can promote toilet revolution, which brings great opportunities for implementing toilet revolution.

1. Millennium Development Goals and Sustainable Development Goals

At the opening of new millennium, the United Nations (UN) Millennium Development Goals (MDGs) unveiled a special horizon - one that the entire developing world has been tasked to arrive at by 2015. To arrive at this moment of achievement, though, the world must first cross the water barrier (ADB/UNDP/UNESCAP/WHO, 2006). On 25th, September 2015, world leaders gathered at the UN in New York to adopt the 2030 Agenda for Sustainable Development, which comprises 17 new Sustainable Development Goals (SDGs). The new SDGs, and the broader sustainability agenda, go much further than the MDGs, among, Goal 6 ensures availability and sustainable management of water and sanitation for all (UNDP, 2015). By 2030, it requires to achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations. In addition, it requires to improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally (UNESCAP/ADB/UNDP, 2015).

Globally, at least 1.8 billion people use a source of drinking water that is fecally contaminated. (UN, 2015). Providing reliable and affordable sanitation facility in rural areas is a challenge in many parts of the world, particularly in developing countries. As roughly estimated, there is approximately 9 billion tons of domestic wastewater discharged every year in rural areas of China (Zhou et al., 2008). The world is striving to meet MDGs and SDGs while China is no exception. Popularization of improved sanitation facility can undoubtedly increase the possibility of achieving some of the MDGs and SDGs. i.e. Target 3 (by 2030 end the epidemics of AIDS, tuberculosis, malaria, and neglected tropical diseases and combat hepatitis, water-borne diseases, and other communicable diseases), besides Target 6 (by 2030 achieve access to adequate and equitable sanitation and hygiene for all and end open defecation).

In such case, toilet revolution can help to ensure environmental sustainability and reverse the loss of environmental resources. It does not imply overexploitation of the existing resources, but improving their management by reducing, recycling and reusing human wastes (Giovanni et al., 2012).

2. Government support at all levels

Since the 18th National Congress of Communist Party of China, the central government indicated the future development direction for the whole nation that infrastructure construction and social undertaking will give priority to rural areas. Sanitation is important to implement Socialism New Countryside Construction. The popularization of sanitary toilet is helpful to improve rural living condition and promote rural civilization, and thereby achieve the goal of building moderately prosperous society.

Toilet revolution has aroused leaders' attention. President Xi Jinping has made special instructions on toilet revolution and civilized tourism in 2015, Premier Li Keqiang has also called for the innovation in the country's patriotic health campaign (The State Council, 2015). The campaign "plays an irreplaceable role" in preventing and controlling the spread of disease, improving hygiene in urban and rural areas and strengthening public awareness. NPHCC, under Ministry of Health (MOH), is in charge of the patriotic health campaign.

Under central government, local governments built up "Leading Group for Toilet Revolution", which is in charge of formulating and promoting toilet and sanitation improvement plan. For instance, eight provinces have held deployment meeting for tourist toilet, eleven provinces have building up province-level leading and coordinating group for tourist toilet revolution up to now. On the 2015 World Toilet Day, NTA, Ministry of Housing and Urban-Rural Development (MOHURD) and Beijing government held the activity of "China Toilet Revolution Mobilization Day". On 1st, April, 2016, NTA and NPHCC together held the activity of "China Toilet Revolution Advancing Day". These activities all indicate the strong support from government at all levels.

3. Environmental protection and resources recovery

Urban-industrial growth is beginning to skew China's water allocation balance. Already, competing demand for water is turning this resource into a basis for conflict (Narain, 2012).

China suffers a lot from environmental pollutants in the form of wastewater. In 2015, the total amount of COD discharge can reach 22.2 million ton, total nitrogen can reach 4.5 million ton while total phosphorus can reach 5.3 million ton. Even if pollutants discharge trends to decline year by year since 2012, the total amount of pollutants is still huge (MEP, 2016).

In term of agriculture sector, the agricultural pollution sources exceeded industrial pollution sources in 2015 for the first time. Ministry of Agriculture set the target that the use of chemical fertilizer and pesticide should become zero growth by 2020. That means, in the coming few years, the use of

chemical fertilizer will still increase until 2020. The up-to-date statistics shows that the total amount of chemical fertilizer application in agriculture can reach 60.0 million ton, among, nitrogenous fertilizer can reach 23.9 million ton (in N), phosphatic fertilizer can reach 8.45 million ton (in P_2O_5), potassic fertilizer can reach 6.42 million ton (in K_2O), the other is compound fertilizer (MOA, 2015).

One person can generate ca. 4-5 kg/y nitrogen, 0.75 kg/y phosphorus and 1.8 kg/y potassium in greywater, yellowwater and blackwater (Larsen and Gujer, 1996; Fitschen and Hahn 1998). More than 90% of nitrogen and phosphorus come from human excrement in the form of urine and faeces. Compared with the chemical fertilizer application amount, if the valuable nutrient elements are collected and recovered in agriculture, this can replace 20% of chemical fertilizer by rough calculation. The community associated great benefits from using human excreta in agriculture, especially if composted, and did not associate risks with the use of composted excreta if it was dry and lacked odour (Jensena et al, 2008). Empirical research has shown that the use of manure significantly improves crop yield, soil fertility and water and moisture conservation (Liu et al, 2014).

4. Diseases prevention and poverty alleviation

Modern medicine indicates that human faeces contains many kinds of pathogens which can cause serious intestinal infectious diseases and parasitic diseases. The amount of untreated faeces sludge discharged into the open environment poses a serious public health risk. For instance, WHO reported that Poor sanitation contributes to 1.5 million child deaths from diarrhoea each year. Chronic diarrhoea can also hinder child development by impeding the absorption of essential nutrients that are critical to the development of the mind, body, and immune system. It can also impede the absorption of life-saving vaccines (Strande et al, 2014).

The potential for pathogen contamination is high, since faeces is the greatest source within the components that make up conventional wastewater (Vinnerås et al., 2006). A 5 m³ truck load of faeces sludge dumped into the environment is the equivalent of 5,000 people practicing open defecation. Adding to this is the heavy load from open defecation of raw faeces excreted in the open by an additional 1.1 billion people who still do not have access to any toilet. The consequences of this waste entering the environment are staggering. In addition, Pathogens have been known to be a major constraint when using wastewater products in agriculture, and since faecal sludge can be highly contaminated, this is a key factor for implementing sanitation systems, which aim to reuse these wastewaters (Magri et al, 2014).

Toilet Revolution requires to achieve popularization of sanitary toilet, which would play an important role in diseases prevention. For instance, biogas sanitary toilet can kill considerable pathogen inside human excreta. (Wu & Xu, 2003). A study was carried out by Sichuan Province Institute of Parasitic Disease Prevention and Control to test the treatment effect of sanitary toilet with biogas plant in six projects. Generally, Faecal coliforms of treated sewage is $> 10^{-4}$. The number of parasitic ovum ranges from 0.565/L–1.074/L. BOD < 50 mg/L. SS < 60 mg/L. Chromaticity is < 100 . These indicators could meet the requirement of Integrated Wastewater Discharge Standard (GB8978-2002) and Sanitary Standard for the Non-hazardous Treatment of Night Soil (GB7959-1987). (Zheng et al., 2006).

As estimated, the input-output ratio is approximately 1:5.3 for retrofitting sanitary toilet. The benefit mainly attributes to the diseases prevents and health improvement. The World Bank estimates that poor sanitation costs the world 260 billion USD annually. From this viewpoint, implementing toilet revolution will definitely alleviate poverty and improve wellbeing.

CHALLENGES FOR IMPLEMENTING TOILET REVOLUTION

Toilet revolution is not just a buzzword, instead, it integrates environment protection, disasters prevention, resources recovery, sustainable development into consolidated whole. Many challenges are still existing and should be overcome for sound development.

1. Insufficient fund and policy support

The independent support policy on toilet revolution is still missing, although some incentive policies have been introduced. The absence of incentive policies make social financing difficult. Enterprises and research institutes should be encouraged to be involved in toilet revolution by incentive policies, such as tax preference. In term of local government initiative, it is suggested that toilet revolution is integrated into assessment index system of government's achievement. This can vastly mobilize the initiative of local governments and urge them to formulate related regulations and plans to implement toilet revolution. What's more, toilet revolution can be integrated into social and economic development plan.

Even if that the total cost of ecological sanitation systems is roughly half of traditional flushing toilet, it still requires initial fund. By rough estimation, toilet revolution requires billions of CNY for new construction. In some cases, when toilet is damaged by natural disasters, the repair of toilet is also short of fund. The fund shortage has become a bottleneck for promoting rural sanitation systems, especially in less-developed areas. The mainly fund support is from national subsidy, the sound market is still at the rudimentary stage (Gao et al, 2014). For instance, the sanitary toilet retrofitting can only be subsidised by government. What's worse, there is no specific subsidy for toilet itself, it has to be normally attached to household biogas program, which is under national debt program. Toilet revolution is often associated with Three Rural Issues (issues about agriculture, farmer and rural area) or Socialism New Countryside Construction, public health, poverty alleviation, environment protection, etc. In such case, the fund from other fields can be partly transferred towards toilet revolution.

2. Region imbalance and lagging approval process

There is imbalance for development of sanitary facility with considerable urban-rural and regional gaps. The penetration rate of sanitary toilet in central and western parts of China are obviously lower than those of eastern regions. Poor sanitation normally exists in poor areas, where the burden of inadequate sanitation is greatest. By 2020, the coverage of rural sanitary toilet should reach 85%, which can be treated as national average target. When it comes to province, five developed municipalities/provinces including Beijing, Tianjin, Shanghai, Jiangsu, Zhejiang will reach 100%, another twelve provinces will reach 82%. There is no specific goal for Tibet yet. This can indicate the imbalanced development of sanitary facility. In some villages, people want a sanitation technology that requires more water just to be able to bring pressure on the government for an increased water supply. In some villages, people reject water-intense sanitation technologies for lack of water.

Toilet revolution is involves in mult-departments. At the level of the State Council, the ministries includes MOH, NTA, MOHURD, MEP, MOA, Ministry of Transport (MOT), and Ministry of Land and Resources (MLR), etc. Generally, NTA is in charge of toilet in tourist areas, which is reported most by news media. MOT is in charge of toilet at the rest areas of highway or railway. MOH and MOA are in charge of sanitary toilet retrofitting in rural areas, MOHURD is in charge of public toilet in cities. MEP is in charge of environmental impact assessment for most toilets. MLR is in charge of land use for toilet construction. However, when one department (e.g. NTA) implements its own aspect, it also needs to coordinate with other departments. It must face a series of approval process from each department. In such case, overall coordination is important. The high-level

coordination group from central government which can coordinate all these ministries, seems missing. At this moment, central government establishes more than 20 leading groups in key issues. For instance, comprehensively deepening reform leading group, network security and informatization leading group, addressing climate change and energy conservation and emissions reduction leading group, etc. It is also suggested to establish toilet revolution leading group, which can coordinate different departments. In addition, the “green channel” for toilet project should be open, in order to shorten the construction time, especially, the approval process for land use.

3. Weak sanitary awareness and low acceptance of new toilets

The public think environmental pollution has become a serious problem for China (Liu et al., 2010). Public awareness towards the problem of wastewater pollution has grown tremendously in recent years (Wolter et al., 2016). However, the education gap between urban area and rural area is still huge. Due to the limitation of education level, toilet and human waste are always treated as taboos, people don't like talking about toilet in public. In addition, there are still many uncivilized phenomena regarding use of toilet in public areas, e.g. tourist toilet. Some people don't take care of public facilities so much, they only focus on own sanitation maintenance but neglect public environment. The early education had a significant association with whether the study households had an improved toilet or not. It was evident that education, water supply and sanitation all had some connection with each other. Therefore, a strong collaboration between agencies that are in charge of elementary education, water supply, sanitation, and public health is necessary for implementing sanitation technology.

Another issue for improving sanitation involves acquiring a sound knowledge of the feasible sanitation systems and technologies which, in the site specific context, can achieve the intended objectives of health, hygiene and wellbeing (Zurbrugg & Tilley, 2009). In spite of many benefits, the lack of knowledge and awareness of new toilets remains a barrier to their acceptance and implementation. Engineers and water/construction industry are resistant to accepting a new toilet they are unfamiliar with (Cordova and Knuth, 2005). With the new sustainability paradigm of the 21st century, interest in new toilets has been growing. With this growing interest and yet gaps in knowledge about the engineering of sanitary toilets, it is now timely to revisit the status of sanitary toilets and bring awareness to this technology so they can be better evaluated for possible adoption as an alternative sustainable sanitation system. Conventional water flushing toilet is still the mainstream technology. In the past, sludge management from onsite facilities has not been a priority of engineers or municipalities, and has traditionally received little to no attention. Several generations of engineers have considered waterborne, sewer-based systems as the most viable, long-term solution to fulfil sanitation needs (Dodane et al., 2012). This lack of awareness and negative image of new toilets is likely to arise from insufficient experience and literature. There are few well-known success stories regarding new toilets. The public may not accept the technology because of perceived odour and maintenance issues, which are the key factor for neglecting new toilets.

4. Lack of R&D and service system

Diffusion of toilets as a pro-poor innovation is a challenge because their successful adoption calls for a change in individual behavior, daily routines and perhaps even social norms (Ramani et al., 2012). Toilet technology is always the primary topic in the R&Ds of toilet revolution. By far, the well-known R&D activity is RTTC-China, launched by BMGF. Although it has been well received, the popularity is limited. Because the innovations BMGF supports can be most immediately valuable in densely populated areas, its main focus is on urban sanitation. This is far from enough for Chinese toilet revolution. R&D on toilet revolution contains process design, device development, ergonomic human engineering, psychology, behavioral science, etc. Many aspects are

still at the starting stage. The support from Ministry of Science and Technology is missing, in such case, China has not formed the sound R&D environment nationwide.

Once one sanitation system is built, a service chain makes access to sanitation a reality. For instance, without collection and transport companies to remove faecal sludge, onsite systems will not function properly. The matched service supporting system includes technical consulting service, operational training service, resident publicity service, public and household facility maintenance service. One barrier to low persuasion of sanitary system is the lack of success project, which is due to better maintenance based on a well-established service system. Construction attributes less to sustainable operation of a sanitary system than maintenance. Unfortunately, there are too many lessons learnt from failure cases in term of maintenance.

WHAT TO DO NEXT?

Toilet revolution is a nationwide action, which requires concerted effort from many department. It is recommended that one department or organization should be built solely aiming at implementing toilet revolution. It should be responsible for coordinating each department, managing local toilet and sanitation system, including the decision-making, R & D, design, manufacture, and maintenance of sanitation system, in a word, considering sanitation system from cradle to grave. A new system should be built, which integrates urban and rural sanitation facilities. Meantime, complete management and service network should be structured to maintain the high-efficiency and sustainability of sanitation system. In term of R&D, integration of orientalism and developed technology, modern technology and traditional custom, high-tech technology and common appropriate technology should be taken into consideration carefully.

Providing sustainable solutions for toilet revolution needs to address not only technology implementation but also cost, ownership and maintenance issues. Technologically, solving the sanitation challenge in China will require radically new innovations that are deployable on a large scale. Innovation is especially needed in densely populated areas, where billions of people are only capturing and storing their waste, with no sustainable way to handle it once their on-site storage—such as a septic tank or latrine pit—fills up. Ground-breaking improvements in toilet design, pit emptying, and sludge treatment, as well as new ways to reuse waste, can help governments and their partners meet the enormous challenge of providing quality public sanitation services. There are many technical guidance available free of charge via the internet for designing and improving complete access to environmental sanitation. In light of China scenarios, especially aiming at toilet revolution, such readable resources in Chinese are of shortage. Concept of toilet revolution should be propagandized step by step.

Toilet revolution should be well aligned with the Eco-San principles. The Eco-San aims to meet socio-economic requirements, prevent pollution of surface and ground water, sanitize urine and faeces, recover nutrient for food production, and save water, energy and resources in a given local context. By being decentralized, requiring little to no water, and producing a value product (fertilizer), ecological toilets offer good promise as a sustainable solution to water and wastewater infrastructure issues (Sasse, 1998; Lens, 2001; Aditi and Sorada, 2011). When applied to the water and sanitation infrastructure, ecological design principles point to human dimension (e.g. incorporating stakeholders in design), learning from nature (e.g. decentralization; elimination of the concept of waste; meeting multiple functions such as treating human waste while producing a value product, limited energy input to the system, and system design specific to location and scale), and integrating nature (e.g. relying on nature's processes for treatment) (Apul, 2010). It is considered more ready and suitable to be applied in rural areas, where the residence is more decentralized and nearer to farmlands than urban. Sustainability with respect to sanitation implies that the system

needs to comprise of collection, storage, transport, and treatment of human excreta, grey water, solid waste and rainwater/stormwater, and the safe disposal or reuse of end products (Katukiza et al, 2012). A sustainable sanitation system should be technically feasible, acceptable to the users, affordable and contribute to health improvement and environmental protection. Population density, settlement pattern, landscape, water availability, household incomes, ownership and socio-cultural issues are also key factors that cannot be ignored. Sustainability of sanitation also requires institutional structures and arrangements to be in place for operation, maintenance and upscaling of interventions.

Toilet revolution requires everybody to access to improved sanitation and sanitary toilet, no matter urban areas or rural areas, rich people or poor people, private or public. There are four institutional challenges to low-cost sanitation: a collective action challenge, a coproduction challenge, an affordability challenge, and a housing tenure challenge. While the challenges are fundamentally institutional in nature, overcoming the challenges depends not just on social and institutional innovation, but also finding or developing technologies that match the institutional challenges as they are manifested locally (McGranahan, 2015; McGranahan, and Mitlin, 2016). Institutionally, toilet revolution should be integrated into social reform and new countryside construction, which is highlighted by central government. Low-cost sanitation technologies should make it acceptable and adaptive to local situation. For instance, composting toilets require little to no water and can therefore disconnect the toilet from both the water supply and wastewater infrastructure (Chirjiv et al, 2014), biogas toilet can make use of human waste and other household organic waste to produce biogas for cooking and return the digestate to farmland as fertilizer, meantime, realize the sanitary disposal of human waste by killing pathogens in digester (Mang and Li, 2010).

Toilet revolution has evolved from a purely technical discipline to one that includes social, environmental, economic and, increasingly, gender considerations (Tilley et al, 2013). The gender distribution for public toilet should be re-considered. It is inspiring that toilet design specification has been modified for the future planning and design. Currently, the cost of new toilets (e.g. vacuum or air-flushing toilet) is estimated from the purchase of a new toilet which is higher than a flush based toilet. From a user's perspective and in presence of low water and sewer utility rates, new toilets are not currently economical. Therefore, the cost is a barrier from a building designer or a home owner perspective. However, the true cost of large scale use of new toilets is not known since system level analyses comparing new toilets to centralized infrastructures have not been researched. So research on scaling up of demonstration project should be studied.

Public toilet services have traditionally been under public procurement provision, unfortunately, there are many experiences in which public provision failed to achieve acceptable results. There are many experiences public-private partnerships (PPP) in this sector worldwide and PPP has become the buzzword in wastewater and solid waste management circles. PPPs are long-term contracts between the public and private sector in which the private sector has responsibility for significant aspects of the building and operation of an infrastructure for the delivery of public services that the public sector should provide while both sectors share risks, costs and benefits (Arbulú et al, 2016). Toilet revolution can also introduce PPPs and absorb private capital to make up the lack of funds, as well as arouse the enthusiasm of the public. Prevailing opinion has it that inadequate toilet and sanitation infrastructure are not a problem. The problems are lack of investment in creating infrastructure and the lack of managerial capacities to operate the systems, once created. The argument leads logically to toilet revolution meaning, on one hand, infrastructure projects created via private investment, through concession agreements and, on the other, handing over public water systems to private parties to "maximise efficiency" and operate (Narain, 2012).

At the end, the sanitation control of human pathogens in the effluent should gain much attention, because health should not be jeopardized by residual pathogens remaining in the water after treatment (Winward et al, 2008; WHO, 2016). Even though various wastewater treatment technologies including centralized and decentralized systems have been developed, the overall treatment capacity is still relatively low in developing countries due to the economic concerns (Wu et al, 2016). Appropriate technology should be highlighted and employed to fulfil the end of toilet revolution.

CONCLUSIONS

Improved sanitation—including waste treatment and resource recovery—is essential to a healthy and sustainable future for the developing world, China is no exception. Toilet revolution requires understanding issues across the entire sanitation service chain, including waste containment (toilets), emptying (of pits and septic tanks), transportation (to sewage treatment facilities), waste treatment, and disposal/reuse. A “good” sanitation system minimizes or removes health risks, is economically viable, and avoids negative impacts on the environment. Ensuring good sanitation systems for the protection of public health and of the environment is of public interest and, therefore, a key duty of the public sector. This duty includes the provision of an enabling framework as well as control and supervision to ensure that these conditions are met for all users. “Sustainable” sanitation however goes a step further. As the core of toilet revolution, sustainable systems take into account economic aspects (financial capital investments required as well as recurring operation and maintenance costs, affordability), institutional aspects (organizational set-up, opportunities for public–private partnership), environmental aspects (minimum energy requirements, opportunities for resource recovery and reuse, environmental impact, health aspects) and finally social aspects (convenience, dignity, acceptability, and willingness to pay or operate).

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