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WATER, SANITATION AND HYGIENE: THE MISSING LINK WITH AGRICULTURE

Daniel Tsegai, Florence McBain, Bernhard Tischbein

Table of Contents

ABSTRACT II

1 INTRODUCTION 1

2 WSH: IMPACTS, PRIORITIES AND RECENT ADVANCES 2

2.1 WATER QUANTITY AND QUALITY FOR DOMESTIC USE: HEALTH EFFECTS *4*
2.2 SANITATION AND HYGIENE: HEALTH EFFECTS *8*
2.3 TRADE-OFFS, SYNERGIES AND ACTION PRIORITIES ON WSH INTERVENTIONS *12*

3 CURRENT CHALLENGES AND GAPS IN WSH 14

3.1 INSTITUTIONAL ARRANGEMENTS *14*
3.2 FINANCIAL ISSUES *16*
3.3 CULTURE *17*
3.4 PHYSICAL ISSUES *17*

4 BEYOND WSH: THE WSH-AGRICULTURE NEXUS 19

4.1 IMPACTS OF IRRIGATED AGRICULTURE ON HEALTH *19*
4.2 INTEGRATING IRRIGATED AGRICULTURE IN THE WSH NEXUS *20*

5 SUMMARY 22

REFERENCES 23

ABSTRACT

Inadequate access to safe water and sanitation services coupled with poor hygiene practices continues to kill, sicken and diminish opportunities of millions of people in developing countries. Various interventions to improve drinking water quality and service levels, sanitation and hygiene (WSH) have been applied, albeit in isolated approaches. Relevant literature focused on assessing the cost and health effectiveness of such approaches. In parallel, irrigation in agriculture, which affects all the water cycle and thus drinking water quality and quantity, has been developed without looking into the consequences for WSH. In this paper, we argue that the 'nexus' approach should take peoples' multiple water needs as a starting point for providing integrated services and thus move beyond conventional sectoral barriers of domestic and productive sectors. Isolated approaches have their drawbacks missing out on positive externalities on health and nutrition outcomes. We also argue that (the prospect of) a holistic approach including WSH and agriculture sectors for a long term health and nutrition impact should be explored. The paper reviews the body of literature dealing with WSH and irrigation agriculture, synthesizes the remarks thereof and concludes with suggestions to unravel the 'nexus' between WSH and agriculture for a long term health and nutrition impact.

Keywords: Nexus, water, sanitation and hygiene, agriculture, intervention approaches

1 INTRODUCTION

Water shortages and contamination lead to disastrous effects on health, nutritional status, labor productivity and general well-being of human beings. Sanitation - a hygienic means of promoting health by preventing human contact with the hazards of human excreta - is also crucial to prevent water-related diseases. Inadequate access to safe drinking water and improved sanitation services and poor hygiene practices continues to sicken, kill and diminish opportunities of millions of people in developing countries. The most affected are developing countries' nationals, most of them children living in extreme poverty.

The world has achieved the Millennium Development Goal (MDG) target of halving the population in 2015 (from 1990 levels) without safe access to drinking water. Nevertheless, 780 million people will remain unsupplied with safe drinking water in 2015. Besides, huge disparities exist between regions and countries (Moe and Rheingans, 2006); disparities between rural and urban settings and disparities between the rich and poor. Regional disparity ranges from only 61% receiving improved water supply in Sub-Saharan Africa to more than 90% in developing regions including Latin America and large parts of Asia (UNICEF and WHO, 2012) . The disparities are even bigger in sanitation. According to Moe (2009), the poor are half as likely to have water access and one-fourth as likely to have sanitation access. With 94 % of the population without access to sanitation in Ethiopia, Chad (92%), Congo (91%), Eritrea (91%), Burkina Faso (88%), among others, Sub-Saharan Africa represents the lowest in access to improved sanitation (Moe, 2009).

The MDG target on sustainable access to basic sanitation is set to be missed. According to WHO-UNICEF (2010), each and every day some 6000 children die of water-related diseases. The right to safe drinking water and improved sanitation remains a promise unfulfilled (Bonn 2011, Nexus conference). Irrigated agriculture accounting for more than 70% of global water withdrawals and related local multi-purpose water use systems and drainage are aggravating the already tense water use competition among economic sectors and affecting domestic water quality. With safe drinking water and improved sanitation alone, approximately 2.4 million deaths and 7% of the total disease burden could be prevented annually (DFID, 2011) while the absence of the services hinders food security, better livelihood, educational opportunities and economic development.

Improving WSH conditions does not only have imperative effects on health and nutrition conditions of the people concerned, it also affects the economy as ill health affects drastically the labor productivity and earning potential of individuals. WHO-UNICEF (2012) underlines that, forty billion working hours are lost in Africa each year due to the need to carry water. In India alone, water-borne diseases cost $600 million annually due to lost production and medical treatment (WHO-UNICEF, 2012). Globally, meeting the WSH MDG would avoid annually $7.3 billion health related costs and global value of adult working days - as a result of less illness - would increase by $750 million (Lenton and Wright, 2005).

Promoting sanitation and hygiene as well as improving the supply levels and quality of drinking water contribute directly or indirectly to all of the MDGs (Hunter et al., 2010; Bartram and Cairncross, 2010). In an attempt to achieve the MDG target and beyond, governments in developing countries continue to exert considerable effort and resources for water quality improvements, increasing water supply levels, improving sanitation facilities and hygiene practices. However, policy actions in this field are pursued too much in isolation missing large positive externalities for health and nutrition outcomes. More so, to our knowledge, no such attempt is made to integrate 'irrigation agriculture'with WSH. Literature on exploring policy options and integrating investment actions on water, sanitation, hygiene and agriculture is scant at best and absent at worst.

The missing link between (irrigated) agriculture and WSH in particular owes to the general trend of governments' priorities on increasing food production through irrigation without a due consideration of health impacts of irrigation agriculture. Besides, increasing demand for irrigation water and domestic water use and the sharpening competition among the sectors calls for a better coordination of the uses and these needs to be based on a more comprehensive understanding of the links and their combined effects on health and nutrition. This paper argues that optimal investment possibilities for an integrated approach including facilitating actions across the WSH sectors should be explored. Furthermore, in the least developed countries, where the majority (73%) of the labor force is engaged in agriculture, there is a need to look beyond WSH, at the multi-purpose water use systems including irrigation agriculture and the links between WSH and agriculture based on a system-understanding of the hydrological cycle under the influence of anthropogenic water uses.

As our review below shows, the nexus effect of such closely linked sectors and the potential link with irrigation agriculture warrants further research. For example, on the link between sanitation and agriculture, an issue paper on the Bonn 2011 Nexus conference argues that 'productive sanitation' is needed which means *"sanitation system solutions that aim at making productive use of the nutrient, organic matter, water or energy content of human excreta and waste water in agricultural production and aquaculture viewed in the perspective of its technical, institutional, social and economical aspects"*.

The objectives of the paper are three fold: (1) Assessing the relevant literature dealing with the objective links among 'water '(quality and quantity), 'sanitation & hygiene' and the health and nutrition impact. In this regard, we focus on the effectiveness of priorities, separate interventions versus integration attempts and the recent advances on WSH (2), reviewing the current challenges and gaps in the WSH sector and attempts made to find a sustainable solution (3), investigating the potential (of) options beyond WSH by linking "irrigation agriculture" to WSH and thus identifying the research gaps and suggesting ways forward. The paper does not address the different settings where integrated attempts would work relatively better.

The paper is structured as follows: the second section deals with a review on the WSH and impacts on health and nutrition with a focus on setting priorities and recent advances on WSH. The third section deals with the current challenges on improving WSH while the fourth section is devoted to looking beyond WSH, specifically the 'WSH-agriculture' nexus. The final section concludes.

2 WSH: IMPACTS, PRIORITIES AND RECENT ADVANCES

The link between water and health intuitively dates back to antiquity. Nevertheless, with the scientific understanding of transmission pathways of water-related diseases, it is only in the last century that a better understanding of the 'complex relations' between water, sanitation, hygiene and health has developed. This understanding has spurred important steps in the last few decades to improve access to water and sanitation worldwide. Yet, as of today one in four persons does not have access to safe sanitation and one in five does not have access to safe drinking water (WHO-UNICEF 2012). With limited resources and the urgent need to tackle the WSH as efficiently as possible, improved understanding of the possible links between WSH sectors, health and nutrition is indispensable. This section reviews evidence on the links between the different dimensions of WSH and their relation to health and nutrition, identifies advances in technologies and approaches to improve WSH most efficiently and provides insights into potential synergies and/or trade-offs between the different dimensions of WSH.

Water-related diseases

The WSH bears a heavy burden of overall diseases and morbidity by causing multiple types of diseases, called water-related diseases. Bradley in 1972 was the first one to establish an etiology of these diseases. He distinguishes four categories of diseases, based on the mode of transmission of the pathogens, as explained in the table below. As the table below illustrates, waterborne diseases relate to diseases where pathogens are transported in water; water-shed diseases are diseases where pathogens have part of their life-cycle in water and water-based diseases relate to diseases where pathogens multiply in water and pathogens which are transmitted through water-related vectors, such as malaria (WHO[1] and Bradley, 1972). To this, Dar and Khan (2011) propose an additional category for chemical contamination of water and metabolic risk from lack of water-carried nutrients.

Tab 1: Bradley's classification of water-related diseases

Category	Example
Waterborne	
Classical	Diarrhea, Typhoid
Neo classical	Infectious hepatitis
Water-shed	
Superficial	Trachoma, scabies
Intestinal	Shigella dysentery
Water-based	
Water-multiplied percutaneous	Schistosomiasis
Ingested	Guinea worm
Water-related insect vectors	
Water-biting	Gambian sleeping sickness
Water-breeding	Onchoceriasis

Source: Hunter et al. (2010)

It is estimated that diarrhea alone, the most frequent water-related disease, is responsible for 4.2% of the global disease burden, which places diarrhea as the 5th highest burden of diseases on a global scale (WHO)[2]. Other diseases related to poor WSH include trachoma, schistosomiasis, ascariasis, trichuriasis, hookworm disease, malaria and Japanese encephalitis and contribute to an additional burden of disease (Table 1). In addition, it must be underlined that children bear the greatest share of this health burden. Cairncross et al. (2010) estimates that, worldwide WSH accounts for 7% of the total disease burden and 19% of child mortality.

Furthermore, water-related diseases are closely related to nutrition. Children with poor nutritional status are more prone to illness and in particular chronic diarrhea, which in turn increases the nutritional deficiencies. On the other hand, repeated bouts of diarrhea or other water-related diseases can lead to nutritional deficiencies. The other causal relationship of nutrition to water and health is through irrigation agriculture. The use of wastewater to irrigation agriculture has health repercussions though it would contribute to water use efficiency (see section 4).

[1] http://www.who.int/water_sanitation_health/diseases/en/

[2] Deaths by causes estimates for 2004:
http://www.who.int/healthinfo/global_burden_disease/estimates_regional/en/index.html

2.1 WATER QUANTITY AND QUALITY FOR DOMESTIC USE: HEALTH EFFECTS

2.1.1 WATER QUANTITY

Despite the long recognition of the impact of water quantity on health, no current international standard exists on the minimum requirements of water quantity levels for a healthy life. As Howard and Bartram (2003) point out, norms of minimum requirements of water per capita per day vary from 15 liters in post-disaster situations to 50 liters (Gleick, 1996). In its definition of safe access to water, the JMP requires a minimum of 20 liters per capita per day (lcpd). These are based on rough estimations of the basic needs for domestic use of water, which Thompson (2001) defines in four categories: consumption (drinking and cooking), hygiene, amenities and productive use. These estimations are averaged and do not reflect the special needs of certain people, such as breastfeeding women and people involved in physical work[3], whose need for water is categorically higher.

i. ***Consumption****:* While lack of water for consumption can lead to lethal dehydration in extreme cases (Howard and Bertram, 2003), an inadequate water quantity more frequently affects cooking habits and diets. Thus, Hebert (1985) observed that water scarcity had an important effect on the growth and nutritional status of children above three in South India. Furthermore, Cairncross & Cuff (1987) found that in villages in Mozambique where water was scarce, food was only cooked once a day compared to villages with higher water availability and where two meals a day were cooked. More recently, van der Hoek et al. (2011) found in their study in North Pakistan a strong association between water scarcity stunting and diarrhea prevalence amongst children under five, after controlling for children´s age, socio-economic status of households and education level of mothers on stunting.

ii. ***Hygiene (for personal and domestic cleanliness):*** water scarcity leads to less hygienic practices, and increasing risks of infections. In a study to understand whether poor hygiene practice were linked to water availability and/or ignorance of hygiene principles Gilman et al. (1993) found that households were actually aware of hygiene principles, but that water scarcity deterred this behavior. Howard (2003) report another study by Prost and Négrel (1989) where increased water availability significantly increased the hygiene water-based practices for children, although VanDerslice et al. (1994) found more limited effects. Cairncross & Cuff (1987) also report that increased water availability in Mozambique was primarily used for hygiene practices. On the other hand, Howard & Bartram (2003) report that other water-washed diseases, in particular trachoma, do not seem to be related to water quantities but rather to the distance to the water source.

iii. ***Amenity use (laundry, car washing, lawn watering):*** although amenity use might not have direct consequences on health, it affects life quality. As Howard & Bartram (2003) note, under water scarcity the use of water for amenities including laundry is often restricted, which might in turn affect general hygiene levels.

iv. ***Productive use (brewing, animal watering, construction and small-scale horticulture):*** this dimension of domestic water use has only been more recently recognized as a necessity in particular for poor households. Health impacts from sufficient water availability for productive usage can be

[3] For men working under high temperatures, estimates are that instead of the 2L of water, 6-7L might be needed (Howard and Bartram, 2003)

expected through an improved diet from garden crops. It can also offer a possibility to develop household businesses which might increase the income of households.

Having briefly reviewed the basic needs for water consumption, it is necessary to look at the underlying constraining factors restricting water consumption.

Water (quantity) consumption determinants

As Howard and Bartram (2003) emphasize, in most cases it is not (only) the pure availability of water that restricts water consumption but accessibility to water sources, as well as the cost and the reliability of water supply.

i. **Access:** Access to water supply is primarily determined by the distance to the water source. Howard & Bartram (2003) observe in different countries the relationship between time and distance to access water supply and the amount of water consumed. They find that when water is within reach of the household, water use increases dramatically. When water access involves a trip that exceeds three minutes, the quantity consumed falls dramatically to roughly 15 liters/capita/day (lcpd). This amount stays unchanged as long as the travel time does not exceed 30 minutes. Beyond that, the water consumption dangerously falls, leading to a critical situation in terms of water consumption. In urban areas however, distance is rarely a constraint in it-self, but the time to fetch water might stretch out because of long waiting queues. This is why the WHO in its guidelines suggests criteria both in terms of time and distance.

ii. **Costs:** According to the Water and Environmental Health at London and Loughborough (WELL) a similar relationship between charging for water and consumption is observed. If water is free and accessible, water consumption increases significantly. This consumption decreases rapidly once tariffs for water are introduced. Above a certain fee, households are not able to pay for basic needs anymore and the water consumption decreases to 'dangerous levels'.

iii. **Reliability:** although evidence is more limited, Zerah (2000) in a survey in Delhi found that low-income families being subject to water supply discontinuity have more limited storage capacities, leading to temporary decline of water consumption. Further problems linked to water supply interruption are related to storage, as it is a well-documented source of vector-borne diseases (Howard et al. 2010).

In sum, water quantity is vital when considering the minimum daily requirements per capita, which are estimated to be around 15-20 lcpd. A large body of literature indicates that once households have access to this minimum water availability, distance to the water source and storage practices, which affect water quality, can have greater health benefits than increasing water quantity on its own. As both quantity and access to water source are closely linked, Howard et al. (2010) advocate for the need to improve levels of water service so that households should be able to have 50 lcpd (source of water should be closer, which enables less storage and reduced risks of contamination). Such water access is, according to them, still lacking for 53% of the world population. In addition, Howard et al. (2010) indicate that additional health gains can be obtained when the water quantity available is much higher, beyond 100 lcpd. Nevertheless, as the authors point out such a level of water availability means that there is a household level supply and the causes for the health gains can therefore come from other reasons than the pure question of availability.

2.1.2 Water quality

Water quality is an essential dimension to provide safe water for domestic uses as well as for irrigation. Similar to water quantity, no international standards currently exist for water quality. As the WHO (2008) explains water quality standards should be developed according to local, cultural, environmental and socio-economic conditions. Nevertheless, the WHO (2008) provides detailed guidelines on safe drinking-water. According to these guidelines safe drinking-water "does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages." Two sources of water contamination exist: biological and chemical.

Water is a solvent for many different pathogens. In its 2008 guidelines, the WHO lists at least 12 different types of bacteria, 8 types of viruses, 7 types of protozoa and 2 types of helminthes which are known to cause human related diseases.

Health risks linked to chemicals are typically lower (Schmoll & WHO, 2006), but also less well understood. Typically, the effects of chemical contamination arise after prolonged exposure. The most well-known adverse effects of chemicals in water are linked to fluoride, arsenic and nitrates (WHO guidelines and Schmoll, 2006). An excess of fluoride causes dental fluorosis (in some extreme cases also skeletal fluorosis) with debilitating physical outcomes. Arsenic, particularly predominant in groundwater in Bangladesh and west-India results in skin-diseases and certain cancers, though the entire epidemiology is not understood[4]. For nitrate, contrary to other chemicals, even short exposure can have dangerous health consequences causing breathing illnesses and infantile cyanosis.

To prevent water from contamination, sources of water need to be protected. While emphasis is on the type of water source, JMP[5] recognizes that this alone is not able to guarantee the quality of water as water quality at source often differs from water quality at point of use, due to handling. To protect water from contamination, multiple barriers from the water source to the consumer are needed to protect the water. Protection and/ or decontamination should therefore be provided at different levels:

<u>Source of water</u>: a first step to manage water quality is to protect the water sources. For this reason, the JMP emphasizes on the level of protection of water sources to define "improved water sources" to have access to "safe drinking water". According to the JMP: "improved" water sources are piped connections to a dwelling, a plot or a yard, water kiosks (especially in developing countries: GIZ, 2009), protected dug wells, boreholes, rainwater collection and standpipes and more generally those that by the nature of their construction, are protected from outside contamination (WHO-UNICEF, 2012). Domestic water comes either from groundwater or surface water. According to Pedley and Howards (1997) in rural and peri-urban settings in Asia and Sub-Saharan Africa, more than 80% of the water used comes from groundwater, as it is often of good quality and does not require any treatment. Further advantage of groundwater (compared to surface water) is the tendency of storage capacity of the aquifer which buffers short-term variability. By definition, groundwater sources are protected, but recent depletion of water tables, the uncontrolled extraction of water, using unprotected dug-wells, unsafe latrines or sewage leakages, seepage and percolation from irrigated areas transporting salt, fertilizers, pesticides and infiltration from rivers and lakes with pollutants are all sources of contamination in developing countries (Cronin et al., 2006). The

[4] Total disease burden is yet unknown. In Bangladesh between 35 and77 million people are at potential risk (Smith *et al.*, 2000).
[5] WHO/UNICEF Joint Monitoring Program (JMP) for Water Supply and Sanitation

increasing report of arsenic groundwater contamination in Bangladesh, Mongolia, China, Vietnam and Thailand, among others, is a recent phenomenon worth mentioning. The impact of groundwater contamination on health has essentially been studied in developed countries. Schmoll & WHO (2006) citing Cronin et al. (2006) report that groundwater contamination has been responsible for 68% of all waterborne diseases outbreaks between 1991 and 1998 in the US.

Point-of-use: In particular for households with non-piped water supply, collection, handling and storage of water are all sources of contamination. Curtis et al. (2000) for example cite a study in 1990 in Sri Lanka that found only 5% of water samples to be contaminated at the source, but 50% of samples contaminated after being drawn. Sources of infection are often linked to handling of water during collection and storage at home. Contamination at the level of point of use is often related to direct health consequences. In their systematic review of relationship between cholera and diarrhea with water quality at point of use Gundry et al. (2004) find a positive correlation between the level of water contamination and cholera, but not with diarrhea. In addition, their study finds that improving water quality at point of use is more effective for health outcomes than at source.

To decontaminate water, many household water treatment (HWT) techniques have been developed and extensively studied over the years. Hunter (2009) in his review of different interventions found that ceramic filter was the most effective intervention of all to reduce the incidence of waterborne diseases, compared to using chlorination and flocculation. On the other hand, Clasen et al. (2007) found that chlorination was the most cost-effective method, though filtration proved to have greater health gains, but (to be) less affordable.

Although it is clear that water needs to be protected and often decontaminated to be safe, the most effective interventions to ensure safe water quality are still debated. According to Cronin et al. (2006) the relationship between the quality of source water and points- of-use and the adverse effects on health are not well understood.

More recently, Clasen et al. (2007b) compare the effectiveness of water quality treatment intervention at the source and at household level to prevent diarrhea and find that household interventions are more effective. Another aspect concerns community water supplies. As Kremer (2007) underlines little evidence exists on the actual benefits in terms of diarrhea reduction of providing piped rural water supply infrastructure, because of problems linked to maintenance of the system and the reliability of the water supply. Majuru et al. (2011) confirmed to some extent this reality. In their study on improved rural water supply interventions, they find that the reliability of the water supply systems was associated with the reduction in terms of diarrhea.

Lastly, some evidence seems to point to the fact that without appropriate hygienic measures, water quality will not be good enough to meet the expected health gain. Curtis and Cairncross (2003) in their systematic review on hand washing find no link between the levels of bacterial contamination at the point of use level and the frequency of diarrheal disease. Confirming this hypothesis, Pickering et al. (2010a) finds in her study that levels of fecal contamination on hands of mothers and children were positively correlated to fecal contamination in stored drinking water within households.

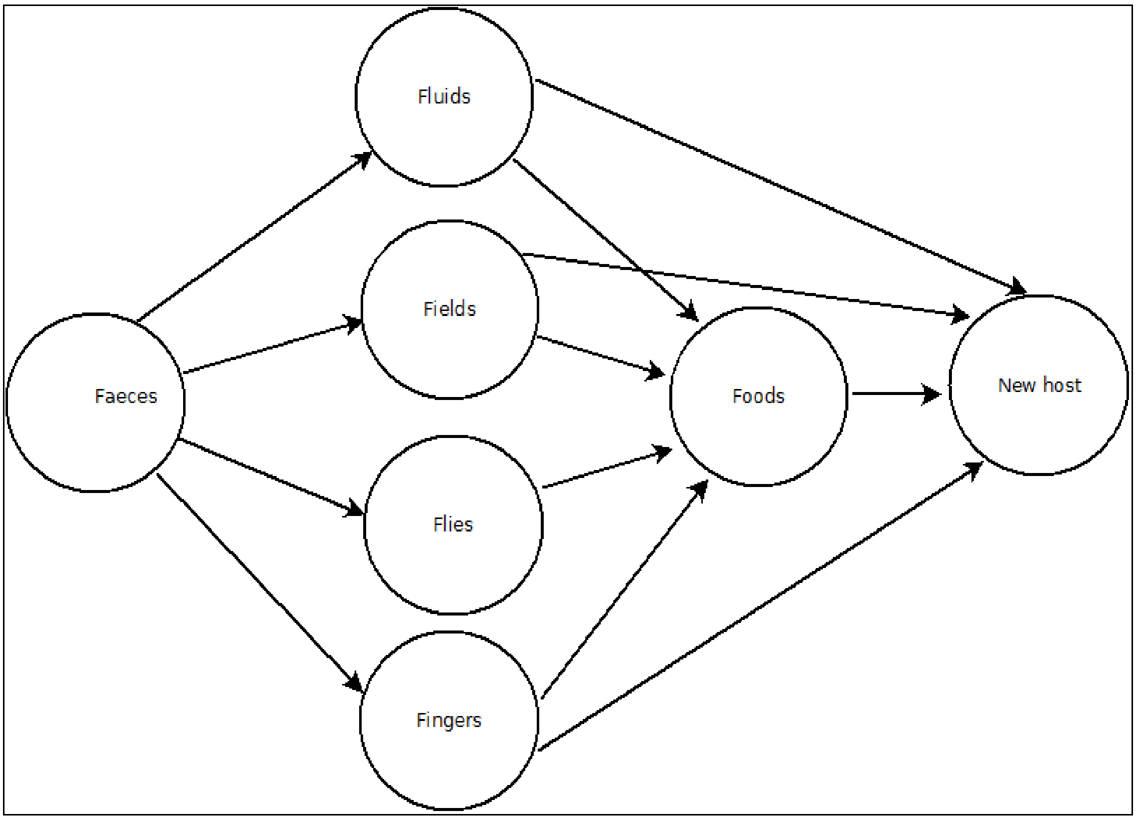
Whereas water quantity and water quality enable to look into the different dimensions of water-related pathogens, sanitation and hygiene focus essentially on reducing barriers to the fecal-oral transmission of water-related pathogens, the most common of transmission of these pathogens.

2.2 SANITATION AND HYGIENE: HEALTH EFFECTS

2.2. 1 SANITATION

The F-diagram (called like this, because every item starts with the letter F) below illustrates the most common transmission pathways of fecal-oral pathogens.

Figure 1: Common transmission pathways of fecal-oral pathogens



Source: Howard and Bartram (2003), page 11 (Modified)

Based on the above F-diagram, Curtis et al. (2000) distinguish primary and secondary transmission paths. Sanitation which ensures a safe disposal of faeces and other hygiene interventions which prevent the primary routes of transmission from fingers and fluids to another host are primary barriers. Secondary barriers are hygiene practices that stop transmission paths of fecal pathogens that have already got into the environment.

According to the WHO-UNICEF JMP program, improved sanitation is defined as "any facility which hygienically separates human waste for human contact". While the JMP has a specific list of different types of latrines to categorize them as 'improved' or 'unimproved', it can generally be said that latrines that do not have a recipient to contain faeces, public/shared facilities and open defecation are unimproved facilities. The JMP estimates that in 2010 63% of the world population was using improved sanitation facilities, leaving behind 2.5 billion people without access to adequate sanitation facilities.

Technically speaking, one distinguishes between on-site and off-sites systems. On-site systems, most commonly latrines, store and/or treat excreta at the point of generation. Off-site systems such as sewage transport excreta to another location for treatment. Off-site sanitation is more complex and is estimated to cost between 20 and 70 times more than on-site systems. A complete piped network and a treatment and/ or a disposal point are integral to the off-site system. In 2001, Carr reports, the Word Resources Institute estimated that at that time less than 5% of all sewages in developing countries received any treatment before being released in the environment, causing an important pollution. A more recent estimate by Homsi (2000) indicate that approximately 50% of waste waters are now being treated in developing countries, pointing to a great improvement, although this is clearly not enough and causing important environmental (and health) damages. In India for example, the Planning Commission of the Government of India (2007) estimates that 80% of surface water pollution is linked to wastewater.

The impact of improved sanitation on health is quite established in the literature. Earlier research by Esrey et al. (1991) estimated that improved sanitation reduced diarrhea frequency by 36%. In another systematic review by Fewtrell et al. (2005) authors find that sanitation reduces diarrhea and other diseases effectively. A recent review by Ziegelbauer et al. (2012) finds similar results in terms of the effectiveness of sanitation in reducing helminthes transmission to humans. Nevertheless, this assessment is only based on two studies, pointing to a lack of thorough evaluation in the field of sanitation. In particular, they call for more research on the types of sanitation solutions which are proposed: off-site versus on-site sanitation solutions. They underline that dry latrines, which can produce useful outcomes after off-site treatment of the excreta, seem to be a promising path and would need to be more researched.

In an effort to better understand the benefits of off-site sanitation solutions in cities, Norman et al. (2010) undertook a systematic review of sanitation with sewage interventions. The authors underline that the studies they reviewed were all observational and none were randomized. They estimate off-site sanitation interventions to have a 30% reduction in diarrhea incidence (though it went up to 60% if initial sanitation conditions were very poor). Nevertheless, the authors have not tried to compare off-site sanitation effectiveness with on-site sanitation solutions.

The health benefits of improved sanitation are uncontested, but as described in the sections that follow, the difficulty of these interventions lies in how to ensure that the facilities are accepted and properly used (and maintained) by their users. In the next section, we elaborate the recent advances related to sanitation and its take-up by consumers and suppliers.

2.2.2 ADVANCES ON SANITATION INTERVENTION

WSH interventions were traditionally technical and focused more on installing water supply points and latrines and less care was given to hygiene behavior changes and maintenance of the systems and much less attention to the demand (take-up) behavior of interventions. According to Jenkins (2004), the traditional approaches have by and large failed to generate demand for sanitation, to produce products or services sustainably beyond the subsidy and to provide solutions replicable at scale. In this section, we highlight sanitation marketing and Community Led Total Sanitation (CLTS) as two examples for the (recent) advances and innovations in the field of WSH interventions.

i. Sanitation Marketing

According to the World Bank's Water and Sanitation Program (WSP), sanitation marketing is defined as an emerging field that applies social and commercial marketing approaches to take to scale the supply and demand for improved sanitation facilities. Sanitation marketing takes more a social approach and 'social marketing'[6] fits more the purpose it serves (Cairncross, 2004). Cairncross presents the development of the market as the only sustainable approach to meeting the need for sanitation in developing countries owing to its advantage of allowing people to choose the services they want and are willing to pay for. It is financially sustainable, cost-effective and guarantees behavioral sustainability. Cairncross asserts that marketing approach encourages the privatization of household sanitation supply and promotes demand and ensures a balance between supply and demand. The four pillars of sanitation marketing are - 'product', 'price', 'place' and 'promotion', which are often referred to as "the four Ps" (Cairncross, 2004). Sanitation design should conform to 'what people want' and not 'how engineers want to design it'- this is what is meant by the pillar 'product'. 'Price' is about selling the sanitation and that keeping the cost down would promote its use by the poor. Latrines should be installed, ideally at the right 'place', the customer's home. The fourth pillar, 'promotion', is about promoting and communicating the product to consumers. This includes advertising, mass media, word of mouth, and anything in between.

Creating demand is the focus of sanitation marketing. Waterkeyn and Cairncross (2005) elaborated on creating demand for sanitation and hygiene through Community Health Clubs in Zimbabwe. Using the Community Health Clubs to change hygiene behavior and building rural demand for sanitation, they found that hygiene club members were statistically significantly different from a control group across key hygiene practices including hand washing, drinking water, rubbish pit, etc. This illustrates that changing the behavior of a group by making it a 'norm' for the communities would improve sanitation and hygiene conditions. Another study which stressed on creating demand for sanitation is conducted by Jenkins and Scott (2007), in which they assessed the drivers of demand for sanitation in Ghana. They studied different settings where marketing approaches could work to accelerate adoption of household sanitation. The analysis was based on three adoption stages: preference, intention, and choice to install a toilet. They found that marketing strategies aimed at the 'preference' and 'choice' stages were successful modes for increasing household sanitation demand and coverage.

Questions, however, arise if and how far effective sanitation marketing is and the conditions under which it works better. A study by Outlaw et al. (2007) confirmed that sanitation marketing is a viable approach to increase sanitation uptake among rural households in Uganda. Another study by Sijbesma et al. (2010) analyzed the sustainability of a rural sanitation marketing introduced in Vietnam. They found that lack of finances and lack of training also related to lack of finances, among others, have hindered sustainability and recommended further assistance to maintain sustainability on promoting institutional capacity.

Sanitation marketing has its shortcoming as well and thus has been subject to debate. Most recently, Güllemann (2012) criticized sanitation marketing as 'non functional' and 'unsustainable' approach. He made his comments based on a study he conducted in Cambodia. According to him "*the current attempts to solve sanitation crisis with market based mechanisms, as is currently en vogue, rather worsens the situation instead of improving it*". He presents simple pit latrines as 'undesirable' and offering only 'temporary' solutions and most households revert to Open Defecation (OD) after a while. They see simple pit latrines as stores of "kaka" that add 'bad luck' to communities. Communities rather claim 'pour flash' latrines as desirable. According to Gülleman, sanitation problems are only being viewed technically and as such no effort is being made to understand the 'cultural and human cosmology perspective'.

[6] The difference between social and commercial marketing (according to Cairncross, 2004) is in terms of who gets the profits from the sale. While the benefit goes to the consumer or the community in the social marketing, in commercial marketing, the profit goes to the funding party.

ii. Community Led Total Sanitation (CLTS)

CLTS, pioneered first in Bangladesh, is a rural sanitation program led by communities to do away with open defecation by facilitating (for) communities to conduct their own assessment of the causes of open defecation and 'triggering' them to take their own collective action for change (Bongartz et al., 2010). The central point of CLTS is that *toilets* alone will not provide a sustainable solution as the utilization of these facilities cannot be guaranteed. An important part of the approach, according to Bongartz et al. (2010), is that CLTS pushes people "to look at, talk about and deal with their '*shit'*".

While most of the previous approaches of sanitation involved subsidies to run the facilities and this subsequently limited the resulted achievements and created unsustainable solutions, the CLTS is free of subsidies and the focus is on behavioral change instead of toilet construction. By raising awareness that as long as even a minority continues to defecate in the open everyone is at risk of disease, CLTS triggers the community's desire for change, propels them into action and encourages innovation, mutual support and appropriate local solutions, thus leading to greater ownership and sustainability (http://www.communityledtotalsanitation.org/page/clts-approach). CLTS has been expanded to most parts of Asia and recently to Africa. It expanded fast in Africa, it is well received and it is now introduced in 32 countries in Africa in three years time (2007-2010).

Moe (2009) elaborates that water and sanitation intervention programs have so far taken their own designs and the implementation of such programs led to 'unsustainable, culturally inappropriate, or irrelevant installations' and thus were ineffective. Moe recommends new interventions should focus on smaller scale; community-based and should promote active involvement by beneficiaries. Research areas suggested by Moe (2009) include social marketing, health behavior research, technical and microbiological investigation, health outcomes and impacts research. New and innovative approaches related to 'technology and delivery', greater dissemination of information on what works and what does not, providing greater training and building capacity in human resources, and greater political and financial commitment.' The Bonn Nexus conference also stresses that CLTS combined with sanitation marketing has improved sanitation coverage (Devin and Kullkman, 2011).

Generally, sanitation involves a change of behavior which is also the key to hygiene. Some authors insist that sanitation alone is not enough without hygiene improvements.

2.2.3 HYGIENE

Hygiene is a broad term encompassing any practices or behavior that can contribute to understand and preserve good-health by stopping infection routes. In the case of WSH, it refers to any practice or behavior that stops fecal-oral transmission of pathogens. Hygiene interventions encompass general awareness and education programs on hygiene behavior, while other intervention measures focus on particular hygienic practices, such as child-care behavior, breast-feeding, cooking habits, washing habits, etc. While breast-feeding has proven to be highly effective to reduce the contamination risks of infants, other measures are more difficult to measure. As Aiello & Larson (2002) underline "attributing a specific hygiene intervention to a reduction in illness is difficult since it is virtually impossible to isolate the effects of specific hygiene measures". Amongst hygiene interventions, the most widely promoted and studied hygiene measure refers to 'hand washing' and will be discussed here.

Recently systematic reviews have tried to isolate the benefits of hand-washing practices. Curtis and Cairncross (2003) found hand-washing could reduce diarrhea risk by 47% at the community level. In a random control trails Luby et al. (2006) found that children under 5 that received soap and hand-washing promotion had a 50% lower incidence of pneumonia and a significant lower incidence in diarrhea. A recent study by Pickering et al. (2010b) compares waterless hand hygiene called 'hand sanitizer' with 'hand washing with soap'. Surprisingly, the alcohol-based waterless hand sanitizer was found to be more effective than hand washing with soap implying further assessments of promoting hand sanitizer in water scarce environments.

While the health benefits of hygienic practices in general are widely accepted, debates in the literature try to understand which hygiene practices are worth to be promoted. As Curtis et al. (2000) emphasize, studies have shown that it is essential for interventions to induce hygienic behaviors to target messages and actions. According to them and based on the F-diagram, hygiene should primarily target first transmission of pathogens path that is by washing hands after defecation. Their review on hygiene practices to improve children´s health supports this hypothesis. Nevertheless, other authors such as Briscoe (1978) have found just the reverse that washing hands before eating was more efficient than after defecation.

2.3 TRADE-OFFS, SYNERGIES AND ACTION PRIORITIES ON WSH INTERVENTIONS

In the past few decades, numerous interventions have been conducted in the field of WSH to improve nutrition, food security and health. As we have seen in the previous section, interventions that exclusively focus on technical aspects or exclusively on cultural ones are doomed to fail. It is necessary to promote interventions that take into account the cultural, psychological and social circumstances affecting the adoption of technology and behavior. But on which segment is it necessary to invest in first? Are some interventions more beneficial in terms of health and nutrition gains than others? This section will discuss synergies, trade-offs and highlight some of the points to take into consideration when trying to define a WSH nexus and propose action priorities for this sector.

i. Water quantity vs. quality interventions

Earlier assessments (Esrey et al., 1985, 1991) of WSH interventions evaluated that water quantity interventions were more effective in reducing water-related diseases, than interventions to improve water quality. Overall though better sanitation (36%) ranked first, followed by hygiene (33%), water quantity (20%) and water quality (15%). 'However, Gundry et al. (2004) argue that the focus of Esrey et al. on water at "source" rather than at "point of use" underestimates the impact of water quality as this does not take into account the handling and storage effect. A more recent systematic review by Fewtrell et al. (2005) finds that water quality measures were more effective than water quantity interventions. Confirming this in a RCT, Clasen et al. (2007a) also found that water quality interventions were effective in reducing diarrhea, even in the absence of other interventions to improve hygiene, water storage or water supply. Based on these findings and suggestions by some of the authors, we propose that water quantity and quality have incremental effects on health: under stringent water scarcity, increasing water access to reach a basic level (20 lpcd) has clear health benefits and outweighs the benefits of improving water quality. Beyond this level, health gains seem to be linked more to water quality interventions. Evaluating the WSH interventions, following Hurricane Mitch in 1988 in Central America, Gelting (2009) found that hygiene had largest impact on health followed by sanitation and then water interventions.

House-water treatments (HWT) are more effective in terms of health gains than treatment at the source, as water contamination between water source and the point of use is important. Health gains seem to depend on hygiene, storage and treatment of water to decontaminate it. Esrey (1996) suggests that it is only when the water supply is delivered on-plot that additional health gains are found. The additional health gains from on-plot water supply could also be linked to a general socio-economic gain. Furthermore, with on-plot water supply, contamination is less likely and the impact of HWT is less important. In industrial countries where water supply is reliable and delivers huge lcpd compared to developing countries, water quality at the source seems to be the determining factor to preserve good health.

ii. Sanitation vs. hygiene interventions

In addition, it appears that in many settings the benefits of sanitation outweigh the health gains obtained by either water quality/water quantity interventions. In his 1996 review based on DHS from 11 countries, Esrey finds that sanitation improvements had greater health benefit in terms of diarrhea reduction, weight and height of children than water supply interventions did. Further evidence indicating the importance of sanitation was found by Checkley et al. (2004) in a longitudinal study of a birth cohort in Peru. They found that 24 month old children supplied with either water from a poor quality water source, limited water storage capacity and low sanitation access were shorter and with more frequent diarrhea diseases. The authors find that though low water storage capacity of households is associated with a higher frequency of diarrhea incidence, increasing storage capacity did not have the full health benefits. Sewage connection seemed to be a better predictor of height than water storage capacity.

As for the overall effectiveness of hygiene interventions, Esrey (1996) and similarly Fewtrell et al. (2005) find such interventions almost as effective as sanitation, while Curtis and Cairncross (2003) in their systematic review of hand washing find an overall reduction of diarrheal disease to be higher than what is found in systematic reviews of other interventions.

In a systematic review regarding the effectiveness of different interventions, Parkinson (2009) concludes that promoting hygiene is the most effective intervention in reducing the incidence of diarrheal disease followed by treatment of water at point of use, sanitation and water supply systems with treatment prior to distribution (in that order), though he also acknowledges the variation of the interventions themselves and the context under which they are implemented.

iii. Multiple vs. single focus interventions

Another important debate concerns the synergies and tradeoffs between multiple and single focus interventions. In their systematic review, Fewtrell et al. (2005) find that a combination of interventions of water supply, sanitation and hygiene is not more effective than any single intervention. However as the authors point out the “multiple” intervention did not include water quality intervention. They claim that if water quality intervention would be included, the multiple interventions may have become more effective. Nevertheless, other authors seem to confirm this finding that there is no additional gain from multiple interventions, compared to single focus interventions. Luby et al. (2006) compare the effectiveness in squatter settlements in Pakistan on using disinfectant-disinfectant approach, compared to hand washing and other water treatment interventions and multiple interventions and find no additional gain from multiple interventions. In a complete contrast to the above, Gelting’s (2009) findings are in favor of multiple interventions. As mentioned above, he evaluated the interventions that followed the Hurricane Mitch in four Central American countries (Nicaragua, Honduras, El Salvador, and Guatemala) in 1988 and no single intervention by itself had a “measureable statistical impact” while the combination of the three (water, sanitation and hygiene) interventions had significant impact on reducing childhood diarrhea. However, the situation after the hurricane Mitch may have been specific and therefore conclusions drawn from that situation may be difficult to transfer to mid- or long-term measures.

Hutton et al. (2007) find that all kinds of interventions that aim to improve water and sanitation facilities are cost-effective. They made their remark based on a study of 11 developing countries and for every 1 dollar invested, 5-46 dollars benefits are achieved. The benefits as noted by Hutton et al. (2007) are “time savings due to easier access, gain in productive time and reduced health care costs saved due to less illness, and prevented deaths“. In a similar study by Haller et al. (2007), they estimated and compared the health effectiveness of increasing access to improved water supply and sanitation facilities, increasing access to in-house piped water and sewerage connection, and providing household water treatment in ten ‘WHO sub-regions’. They found that all interventions are cost-effective and household water treatment was most cost-effective while improved access to piped water supply and sewage connections on plot had the largest health impact. The health outcome as measured by disability adjusted life years (DALY) varied a lot between these interventions. It ranged between US$ 20 per DALY averted due to disinfection at point of use and US $13,000 per DALY averted due to improved water and sanitation facilities.

To our knowledge, none of the studies has attempted to see if integrated investments on water quality, supply, sanitation and hygiene would be more cost or outcome effective than isolated approaches. The link to agriculture is even more scant in literature.

Lastly, another aspect to consider when defining priorities for WSH is the different needs and effects of WSH at different stages of life. While it is generally accepted that children under five bear the greatest share of the WSH burden, different needs according to different ages are less well understood. Hebert (1985) for example finds that for less than three years old children the principal determinant of health was the water quality, whereas for children above three water quantities available at household level were more determining. One possible explanation is that children under three are weaned, which is a critical period to build their immune system and the quality of water will be determining.

3 CURRENT CHALLENGES AND GAPS IN WSH

For a better understanding of the future of water supply and sanitation (WSS) and the reasons for the problems that persist in the poor water and sanitation coverage, it is first necessary to analyze the issues related to the sector more closely and to identify the challenges in the field. Though the important factors hindering the progress of WSH differ by regions, countries and even at household and individual levels, in many cases the most common problems which are most prominent in literature fall into four categories: institutional, financial, cultural and physical.

3.1 INSTITUTIONAL ARRANGEMENTS

Institutions have been defined and perceived differently by different scholars. Highlighting the importance of institutions without a common understanding about institutions does not serve its purpose. One of the mostly widely accepted definitions is that of North (1990,: 3-4) where he opens his seminal book on ‘institutions and institutional change’ with the passage that “*Institutions are the rules of the game in a society or more formally, are the humanly devised constraints that shape human interaction…In the jargon of the economist, institutions define and limit the set of choices and individuals”.* Lenton & Wright (2005) identify two types of WSS institutional constraints in developing countries – ‘lack of appropriate institutions’ and ‘chronic dysfunction of existing institutional arrangements’. While both are prominent in developing countries, the absence of an institution is a bigger problem at a more macro (national or sub national) level.

Why do institutions matter?

For a properly functioning water supply and sanitation services, relevant institutional structures and policies are fundamental. Khan (1988) argues that globally available water is enough to meet basic human needs, and the real problem is 'not technical but institutional'. Institutions regulate investment decisions and the charges for water and sanitation services and the setting of enforcement standards. Institutions are also meant to bridge the gap between reality on the ground and *policy* at national level. According to Nawab and Nyborg (2009) the institutional challenge facing developing countries is that there is a huge gap between reality at the local level and the policy at national level. The study by Nawab and Nyborg (2009) showed that wide gaps were found between (1) local people's needs, desires and expectations on the one hand and government policies and services on the other, (2) people's practices and 'historical and proposed institutions', and (3) local people's and policy-makers' understanding of issues. For a sustainable water supply and sanitation institutional solution, the study recommended 'realistic', 'people-centered' and transdisciplinary approaches where local actors are included in the decision making process.

The gender dimension: Gender elements are relevant in institutional issues of water and sanitation. Regarding water, men and women have different interests in and derive different benefits from availability, use, and management of water. Women are primarily interested in water for domestic purposes- washing, drinking, and cooking- while men would focus on irrigation. So, intervention programs should pay attention to gender analysis (Lenton & Wright, 2005). As regards to sanitation, Tearfund (2007) find that the perspectives of women and men on sanitation facilities are also diverse. The right incentives to improve water and sanitation in poor communities owing to the expectation of low return is also another institutional dimension worth mentioning while accountability and sound regulatory systems are also necessary for a properly functioning institutions (Lenton & Wright, 2005).

Capacity building is another important element of WSH institutional arrangement. Whether technical, financial, managerial or social, human capacity building is at the heart of the institutional problem in developing countries to be able to operate, construct, manage and maintain water and sanitation services (Lenton & Wright, 2005). Ayibotele (1988) had singled out 'education' at all levels as the most cost-effective and relevant alternative for improving drinking-water supply and sanitation programs. The multi-faceted nature of WSH necessitates diverse disciplines and skills to improve sanitation and hygiene provision (Tearfund, 2007).

In sum, Jouravlev (2009), taking the case of Latin American countries, comes up with 6 main institutional priorities for improving WSH conditions: "*(1) strengthening the professional, technical, and financial capacity of the regulatory entities and ensuring their independence and stability; (2) developing procedures for accessing the internal information of regulated companies, especially regulatory accounting and monitoring of purchasing and contracts with associated companies; (3) promoting the participation of consumers and civil society in general in the regulatory process; (4) improving arbitration mechanisms and dispute resolution procedures; (5) strengthening regulatory frameworks, for both public and private service providers, based on the notions of fair and reasonable rate of return, good faith, due diligence, and duty of efficiency; and (6) conducting a critical analysis of available options for service provision and structuring them in such a way that they do not become a burden on the economy or the citizens, or ultimately a regressive factor that hinders socioeconomic development.* "

Generally, institutions are important for the functionality and sustainability of the WSH. Human capacity building is one of the most frequently mentioned institutional priorities in literature.

Different institutional views on 'water' and 'sanitation'

While water is considered a human right, sanitation is treated as commodity (Moe, 2009). A household survey on the views of water and sanitation by the population of the Philippines and Benin indicate that sanitation is rarely related to health but to dignity, privacy, prestige, comfort, etc. (Cairncross, 2004 cited in Moe, 2009). Governments have put less effort into sanitation and more into water provision (Lenton & Wright, 2005; Moe, 2009). According to Moe (2009) investment funds spent on water infrastructure were four times that of sanitation in Sub Saharan Africa, Asia and Latin America. Taking the case of Bolivia, Moe (2009) recommends four measures necessary to tackle the problem of slow progress on sanitation (compared to water): (1) development of low-cost sanitation models, (2) examining and stimulating consumer demand, (3) creating small sanitation businesses to meet this demand, and (4) establishing microcredit systems to help finance sanitation purchases. Differentiating between water and sanitation, Kooy and Harris (2012) find that institutions, actors and incentives that influence the provision of safe drinking water differ substantially from those that influence the provision of improved sanitation.

Nevertheless, both water and sanitation seem to have witnessed slow progress. The reasons according to Moe and Rheingans (2006) are: (1) inadequate investment in water and sanitation infrastructures, (2) lack of political will to tackle the tough problems in this area (Tearfund, 2007), (3) the tendency to avoid new technological or implementation approaches and apply conventional water and sanitation interventions, without community involvement, over and over again even when they are inappropriate for the specific environment and community needs, and finally (4) failure to conduct evaluations of water and sanitation interventions to determine whether they are successful and sustainable. Owing to the perception that WSS has lower returns compared to investments in many other sectors (roads and energy, for example), the political will and governments' commitment to allocating adequate national resources to the WSS sector remains poor (Lenton & Wright, 2005).

3.2 FINANCIAL ISSUES

According to Lenton & Wright (2005), the richest are twice as likely to use improved water source and four times as likely to use improved sanitation. Money matters not only to construct new water supplies and sanitation facilities but also to maintain them and this needs local capacity to recover the true costs without reliance on external donors to maintain sustainability. Poverty and thus lack of funding is one of the most important barriers for improving access to water and sanitation services. Lenton & Wright (2005) find that poor households cannot afford the costs of improved water and sanitation services and the poor pay a relatively higher proportion of their incomes to these services than the rich. Citing WHO-UNICEF (2000) and the World Bank (2004), Lenton & Wright (2005) estimated the relationship between per capita income and share of population with access to water supply and found a clear positive relationship meaning with the increase in per capita income of a country, the share of population with access to water supply also increased. Weak local financial markets, a recent decline in private investment, effective maintenance all require money and donors' financial assistance and the recognition that the poor cannot bear the full cost of improved water supply and sanitation services would be a great step forward.

Tearfund (2007) elaborates financial constraints as one of the constraints in water supply and sanitation services in Sub-Saharan Africa[7]. It stressed that 'income generating activities' were preferred to sanitation and water facilities when it comes to provision of loans by public and private

[7] Exceptions are Benin and Kenya, where micro financing seems to be more developed (Tearfund citing World Bank WSP, 2003)

financial institutions and loans are usually provided at high and unaffordable interest rates for the poor and no long repayment period is offered to the poor.

3.3 CULTURE

Culture is a set of shared symbols, beliefs, and customs that shape individual and group behavior (Goodenough, 1999 as cited in Anderson, 2009). The World Water Day 2006 focused on water and culture. It noted that *"Water is not perceived the same way in Africa as it is in Asia or in Australia as it is in the Amazon. The role that water plays in shaping the lives of people can be seen in the huge variety of water-related religious practices, spiritual beliefs, myths, legends, and management practices throughout the world."*

The views on WSH and its impact on health are fundamentally related to cultural differences. Tearfund (2007) report differences in the views of adults and children as well as differences in household circumstances may influence their use of sanitation facilities. Ethnic groups may also have varying beliefs and customs in sanitation facilities. Tearfund also note that the difference between urban and rural residents' attitude on sanitation and hygiene has its contribution to the differences in the use of sanitation facilities. Anderson (2009) elaborates four points on the influence of culture on WSH: (1) shaping how people perceive and interpret their environment, (2) influencing how people structure their community and social life, (3) determining what is perceived as a priority in the community, and (4) serving as both an enabler and a barrier to acceptance of new ideas and interventions. According to Anderson (2009) successful interventions will not only recognize but also understand the local culture. Researchers should not see culture as a barrier, but rather as an opportunity to ensure the sustainability of their interventions.

3.4 PHYSICAL ISSUES

According to Lenton & Wright (2005) reaching out to scattered rural areas or more dense urban settlements which are remote in terms of accessibility is a 'design problem' for engineers.

Physical availability of water itself is a hindrance (about 31 countries are designed as the most water scarce countries in the world by UNESCO,) and this affects in itself the costs of investing and improving WSS services. The costs of improving WSS are context specific and the solution mostly lies beyond WSS sector. Investing in infrastructure to improve water supply for irrigation, domestic, industrial purposes through better policy need a solution that goes beyond the WSS sector (Lenton & Wright, 2005). Arsenic contamination, salinity, guinea worm infestation, or groundwater depletion are also other physical factors that need to be overcome to ensure a safe drinking water supply.

Constraints to improve WSS lie mostly outside the sector. Other challenges arise from physical pressure on water resources and WSH infrastructure. This is linked to climate change and water resources depletion. Increasing research indicates that climate change will put both water and WSH infrastructures under increasing pressures. For Calow et al. (2011) water will be the primary medium through which climate change will impact people and their ecosystems. According to the authors, both observational and climate models indicate that climate change will affect freshwater resources. This is further underlined in Costello´s projection of the impacts of climate change on health. They predict that infectious diseases will primarily arise from extreme climatic events.

Climatic factors also play a role in a country's ability to provide and maintain water supply and sanitation services for its citizens. The droughts and floods coming along with climate change are examples. Physical constraints hinder obtaining/gaining water during dry periods such as building costly infrastructure, though rainwater harvesting could also be an option. As Howard et al. (2010) explain the impact of climate change on water, sanitation and health will be felt through changes in the water cycle: due to less predictable rainfall, extreme weather events such as droughts and floods which will affect water sources. Furthermore, global warming which will accelerate the melting of glaciers being a key water storage in many regions of the world and will be accompanied by sea-level rise which will affect the salinity of many aquifers in coastal regions. Howard et al. (2010) assess the resilience of water supply and sanitation systems against forecasted climate changes by 2020 and 2030. They find that very few technologies in the WATSAN are adapted to the predicted changes linked to climate change, urging to develop more resilient friendly WATSAN approaches.

Other authors, such as Vörösmarty et al. (2000) predict that growing pressure on water will primarily come from population growth rather than climate change by 2025. Indeed, as a UN report in 1994 already indicated growing population with domestic needs for water, expanding agriculture and industries and increased need of water for clearance (sewage and other wastes) are putting water resources under increased pressure as well as putting water uses under increased competition. A change of nutrition behavior towards more water-demanding meat consumption is also an influential driver. In addition, fast growing urbanization is putting water supply infrastructures and sanitation/sewage systems under increased pressure. Lastly, many countries have a lack of management regarding water resources. This causes uncontrolled use of water, leading to deplete water resources. In India for example, where groundwater table depletion is already acute in many states, the Planning Commission recognizes that there is an urgent need to better manage water resources, but the appropriate legislation is lacking. A satellite based evaluation of groundwater depletion in India (Rodell et al., 2009) also warns that the lives of more than 110 million Indians are at risk if the current unsustainable water uses is reversed.

Tearfund (2007) goes beyond the above mentioned issues and portrays other factors constraining WSH in developing countries. i) The lack of a recent and reliable information on WSH condition citing the difficulty of getting information on the WSH needs and demands of remote rural areas. ii) The lack of clear coordination over which institution is responsible and for which function, sanitation commonly administered under Health or water departments or a separate ministry of sanitation; it is argued that instead of looking for the 'right institutional home' for WSH, 'establishing the links between institutions' would be the right approach. iii) As such donor's agenda would also prove to be a barrier as donors in donor dependent countries influence sector policies which may not necessarily reflect the reality; iv) Low capacity to absorb funds would also hinder WSH effective implementation: "*It cannot simply be assumed that more resources will rapidly translate* into improved outcomes"; v) Lack of service providers and lack of access to credit; vi) Lack of communicating in an effective and "strong" way. As cited from WSSCC[8], *"Statistics make no impact on people, so that it is not enough to state to villagers that diarrhea kills x thousands of children in their country every year … The real challenge is to make clear the links between common illness and the practice of e.g. open defecation"*.

[8] WSSCC is here citing the words of Surjya Kanta Mishra, Minister for Health and Family Development in West Bengal, India, a former doctor and local government leader, who apparently helped launch a well-known pilot project in Medinipur and thereafter promoted a 'total sanitation' campaign in West Bengal.

4 BEYOND WSH: THE WSH-AGRICULTURE NEXUS

4.1 IMPACTS OF IRRIGATED AGRICULTURE ON HEALTH

When looking at the linkages between agriculture and health and nutrition, irrigated agriculture deserves special attention for several reasons: (1) irrigated agriculture is practiced in many regions with a currently problematic WSH situation, (2) irrigation based on open irrigation canals, traditional furrow and basin irrigation methods and open drainage ditches lead to direct contacts with domestic water use, (3) irrigation and drainage systems are characterized by intensive water fluxes (surface and subsurface water) driving matter dynamics and as a consequence, impacting severely the hydrological cycle and further water uses/users. The quality and quantity of water used for farming determines both the quantity and quality of crops and thus affects the farmers and their family for their health and nutrition status. The quantity of water available for agriculture has been observed by the FAO[9] to have positive effects on farmers and their families in many parts of Sub-Saharan Africa.

Steele & Odumeru (2004) underline the link between the quality of the water used for agriculture and the quality of the food produced. When irrigation came from untreated waste water, a significantly higher level of waterborne pathogens was found in fruits and vegetables. The health impact of irrigation-water quality on the health of households was further confirmed by Cifuentes (1998) in Mexico[10]. The author finds that children from households irrigating with untreated wastewater had a 33% higher risk of diarrheal diseases than children from rainfall villages or children from households exposed to the reservoirs effluent. Irrigation with poor-quality-water was further associated with a five-time higher risk of lumbricoides infection when compared to children from rain-farming villages. The health consequences of the irrigation's quality only seemed to impact children though.

A better understanding of the interrelations between WSH and irrigated agriculture can be achieved by an approach which is based on the following considerations:

(a) (Raw) water for domestic use (and irrigated agriculture) is taken from the hydrological cycle (blue arrows: Figure 2) and after use via sanitation practices with changed quantity and quality released into the hydrological cycle (red arrows; Figure 2).
(b) Water released after use from irrigated agriculture and WSH influence the quality of surface and groundwater resources.

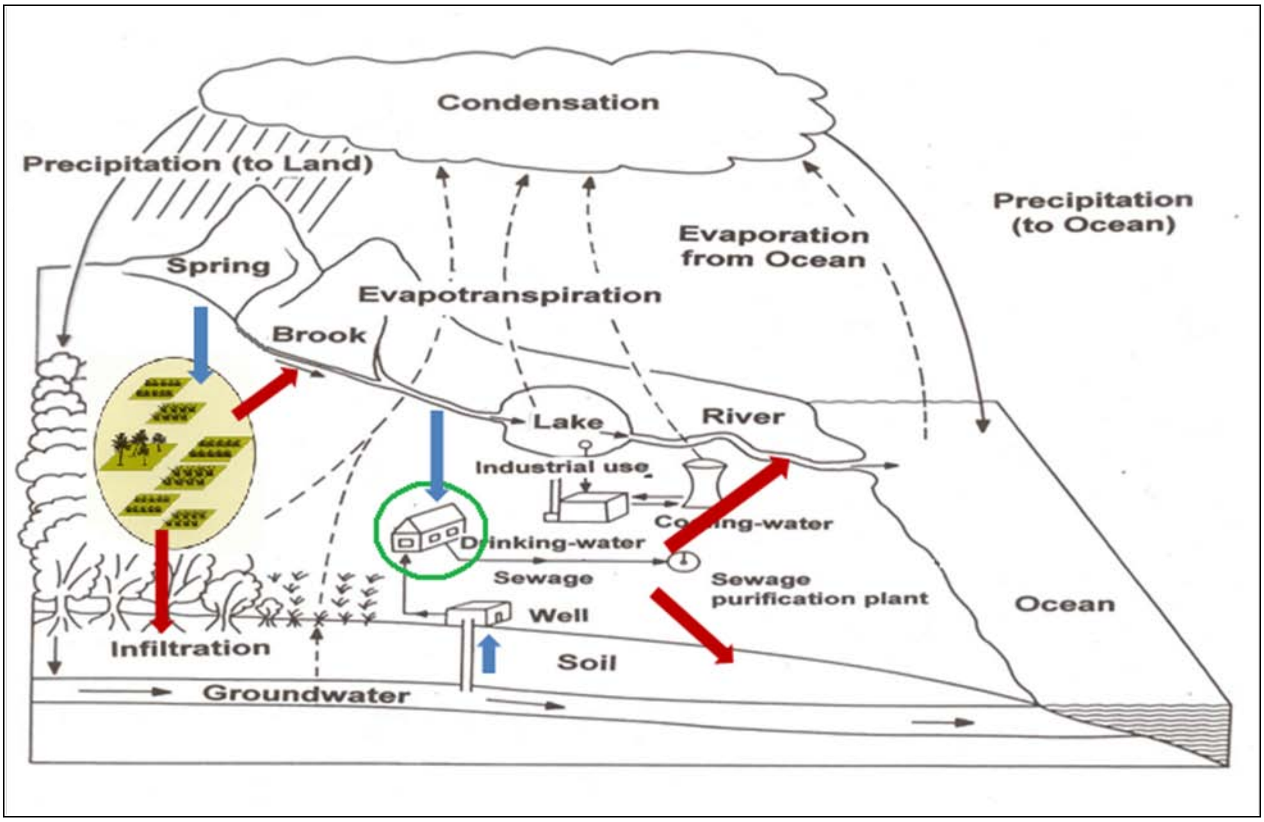
Taking the system approach, three major consequences can be derived:

(1) WSH and irrigated agriculture might compete for water resources of appropriate quality. This competition is expected to sharpen in future due to an imbalance between increasing demand (population growth, change of nutrition behavior towards more water-demanding food) and limited water resources of good quality and an increasing variability due to climate change.
(2) WSH and irrigated agriculture influence the fluxes and water quality within the hydrological cycle.
(3) Mutual influence (and conflicting situations) in terms of quantity and quality available for WSH and irrigated agriculture might arise: either directly -in multipurpose systems- or indirectly -via

[9] http://www.fao.org/News/2001/010305-e.htm
[10] http://www.tandfonline.com.ezproxy.ub.unimaas.nl/doi/abs/10.1080/09603129873480

the hydrological cycle (with the water fluxes and matter flows driven by water fluxes) - depending on the surface or subsurface systems as interface.

Figure 2: WSH withdrawing water from and releasing water into the hydrological cycle



Source: Bick (1993), modified

4.2 INTEGRATING IRRIGATED AGRICULTURE IN THE WSH NEXUS

Aiming at easing an eventual competition between WSH and irrigated agriculture for water resources in terms of quantity and reducing potential disadvantageous impacts on water quality, the above mentioned consequences can be utilized by the following approaches:

(1) interventions within the irrigated agriculture (a) to raise the currently rather low efficiencies of irrigation, (b) to improve spatio-temporal matching of water requirements and (c) to enhance the coordination between irrigation and application of further agricultural inputs (for example: application of fertilizers and plant protective agents) will lower the water withdrawals for irrigation purposes and reduce the output of harmful substances from irrigation and drainage schemes into the hydrological cycle.

(2) knowledge on the water fluxes and the matter flow interlinking the output of irrigated agriculture into the hydrological cycle and the withdrawal of water for WSH can be utilized for making best use of (self-)purification capacities of aquifers and basins; utilizing these functions is a low-cost option to improve quality of raw water and in turn to minimize the expenditure/cost for water treatment; to conserve and support the (self) purification function of aquifers (an

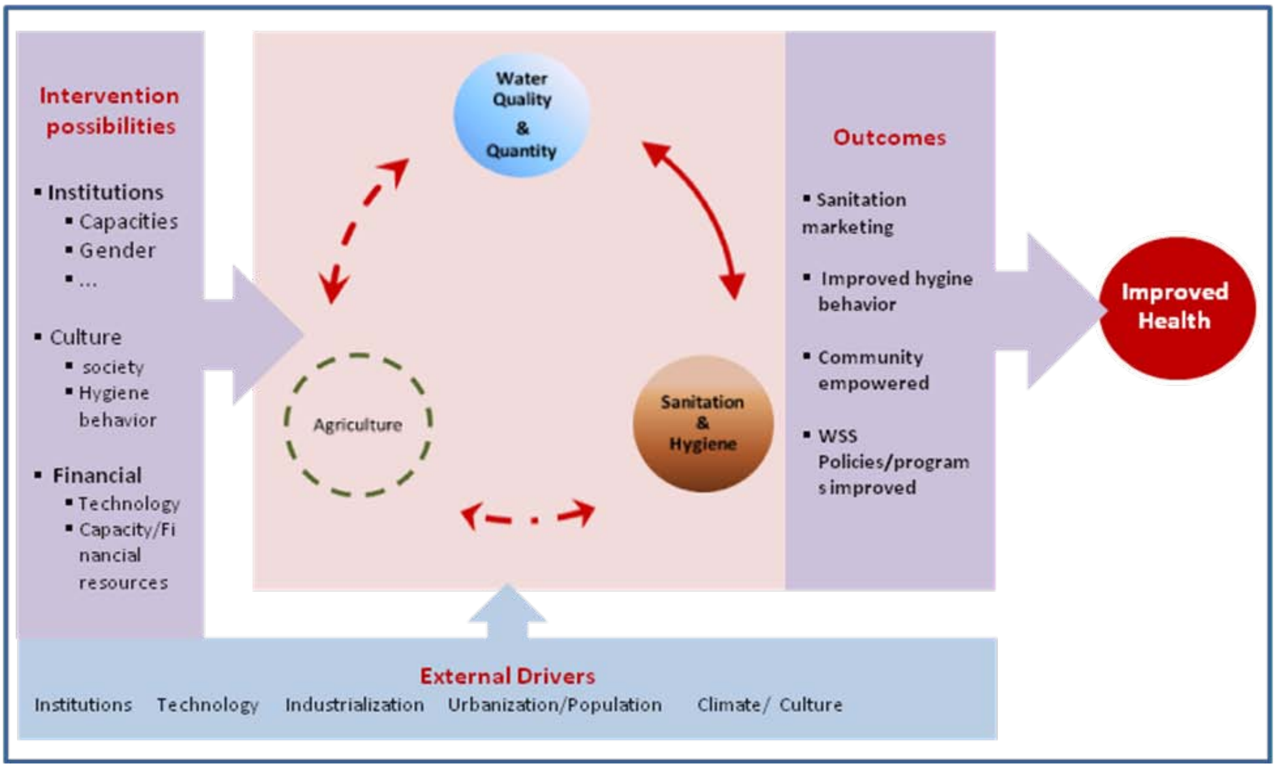
important ecosystem service), protection zones with appropriate land use (for example: forest) between agricultural fields and the location of groundwater wells need to be established.

(3) Stronger synergies among WSH and further water uses at household or community level can be achieved by allocating water supplies with different quality to water uses requiring respective water qualities (for example: supply gained by water harvesting (from roofs) to irrigate gardens in peri-urban areas; waste water as an additional source at agricultural fields with non-food production).

Developing an appropriate procedure to utilize the inter-linkages between WSH and irrigated agriculture should be based on the following steps:

(1) analyzing the requirements in terms of quantity and quality of water by WSH and irrigated agriculture based on a (hydrological) system approach
(2) modeling the water fluxes and matter flow by inter-linking irrigation schemes and settlements requiring WSH and assessing the mutual impact on water quantities and qualities and thus health
(3) working out protection zones and measures
(4) deriving allocation strategies to make optimal use of multi-quality resources

Figure 3: Conceptual Framework on the nexus of water (quality and quantity)-hygiene-sanitation and agriculture



Source: Own design based on Project proposal submitted to Bill & Melinda Gates Foundation

We conceptualize on the possible nexus effect between WSH and irrigation agriculture. Various actors (intervention possibilities in Figure 3) including institutions, culture and financial issues would influence the nexus, nexus outcomes and the dynamics therein (see section 3). Potential intermediary outcomes comprise sanitation marketing, improved hygiene behavior and improved policies, among others. The major exogenous factors catalyzing the nexus for a long term health impact are also shown in Figure 3 termed as external drivers.

5 SUMMARY

The missing link between WSH and (irrigated) agriculture in the past owes to the general trends of governments' focus on sectoral policies, missing out on the inter-sectoral links. Governments' policies for WSH primarily focus on infrastructure and to a certain extent on health outcomes. Agricultural policies focus on increasing food production without due consideration on health impacts of irrigation. More so, increasing demand for irrigation water and domestic water use and the sharpening competition among the sectors calls for a better coordination of the uses and this needs to be based on a more comprehensive understanding of the links.

In view of the hydrological cycle, the intensity of water flows which increased with extension and intensification of irrigated agriculture determines the strength of the health-agriculture links. In the governance front, we argue that policy actions in the WSH field are pursued too much in isolation missing large positive externalities for health and nutrition outcomes. This is especially the case for agriculture and WSH linkages. Literature on exploring policy options and integrating actions on water, sanitation and hygiene is scant at best and absent at worst. This paper argues that optimal investment action possibilities for an integrated approach including facilitating actions across the WSH sectors should be explored. In view of this, the inclusion of agriculture in the nexus based on a system-understanding of the hydrological cycle under the influence of (anthropogenic) water uses is indispensable. As our review shows, the nexus effect of such closely linked sectors and the potential to the link with irrigation agriculture warrants further research.

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