International Institute for Water and Environmental Engineering (2IE)

TECHNICAL SOLUTIONS FOR BETTER ACCESS TO WATER AND SANITATION IN DRY SAHELIAN AREAS

Dissertation in partial fulfillment of the requirement for the award of the Degree of

Specialised Master in

Humanitarian WASH

(Water, Sanitation and Hygiene)

Done and publicly presented on 07th November 2015 By :

Félicien SEBAHIRE

Under supervision of **: Dr. Yacouba KONATE**
(PhD, Lecturer and Researcher at 2IE)

Evaluation panel members :

President : **Mr. Mougabe KOSLENGAR**

Members and correctors: **Dr. Yacouba KONATE**
Mr. DIAFAROU Moumouni
Mr. ADUGNA Amaeh

Promotion 2014/2015

Institut International d'Ingénierie Rue de la Science - 01 BP 594 - Ouagadougou 01 - BURKINA FASO
Tél. : (+226) 50. 49. 28. 00 - Fax : (+226) 50. 49. 28. 01 - Mail : 2ie@2ie-edu.org - **www.2ie-edu.org**

QUOTATION

Water is life, let us struggle for our life through sanitation and hygiene practices !!!

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DEDICATION

To the Almighty God for His powerful protection and guidance;

To my Mother and Late Father

To my beloved brothers and sisters

To my Aunts and Uncles

To my Colleagues

ABSTRACT

The Sahel area is so called dry region as it is characterized by insufficient water sources, short period of rainy season. And again it has poor infrastructure, poverty, less sanitation and hygiene practices.

This project report is based on improving environmental hygiene and health by increased access to safe water supply, a proper excreta disposal, run off and waste water disposal, collection and disposal of refuse and medical waste, effective vector control interventions and proper education of sanitation and hygiene promotion. An overview of water and sanitation documentations, the analysis of actual status of Sahel region in terms of technical problems and solutions about water and sanitation access and the knowhow were dealt in this report. During our research project, the main problems in Sahel region have been seen to be based on insufficient knowledge, unimproved facitlities, poverty and inadequate policy on water and sanitation. The solutions to these problems are to use new technology by rehabilitating and constructing more WASH facilities. We can reach this by investing in water and sanitation projects and creating the oriented actions initiatives from both governments and its stakeholders (WASH actors). For one hand they can be solved through comprehensive management of water and sanitation resources and its demand. On the other hand, the provision of both water and adequate sanitation was found to be by bringing new infrastructure, maintaining the existing ones and behavioural change of the population in water and waste management. Finally, other researchers and engineers in water and sanitation field were invited to deepen this work so that at the end of the day we will have healthy and wealthy population able to sustain their development.

Key Words : Safe water ; Sanitation and Hygiene ; Technical solutions ; infrastructures ; Development.

RÉSUMÉ

La région du Sahel est dite sèche car elle est caracterisée par une insuffisance de ressources en eau et une petite période de pluie par an. De plus, elle presente une insuffisance en infrastructures, la pauvreté aigue et un manque de pratique de l'hygiène et assainissement.
Ce rapport de projet est basé sur l'amélioration de l'hygiène environnementale et de la santé de la population. Pour ce faire, il est necessaire de construire des ouvrages d'approvisionnement en eau potable et de réhabiliter ceux qui déjà existent dans la zone. Il convient aussi de mettre en place des techniques d'une bonne gestion des boues de latrine ainsi que des eaux usées. A cela s'ajoute une bonne collection et élimination des réjets ménagers et médicaux et ainsi qu'une éducation sur le contrôle des vecteurs de maladies liées à l'eau, hygiène et assainissement. Dans ce rapport, vous trouverez l'ensemble des revues sur l'eau et l'assainissement, l'analyse de la situation actuelle de la région du Sahel en termes de problèmes et solutions techniques concernant l'accès à l'eau et à l'assainissement. Dans la région du Sahel, il est demontré que les problèmes principaux sont dus à l'insuffisance du savoir faire, au manque d'infrastructures et technologies, à la pauvreté et la mauvaise politique en matière de l'eau et de l'assainissement.
Les solutions à ces problèmes sont l'utilisation de la nouvelle technologie en réhabilitant et en construisant des infrastructures de WASH. A cet effet, il convient d'investir dans les projets de l'eau et de l'assainissement, de créer des actions bien orientées entre les gouvernements et leurs bailleurs de fond (acteurs en WASH). D'une part ils peuvent être résolus par la compréhension de la gestion des ressources en eau et assainissement et leur besoins. Et d'autre part, l'accès à l'eau et à l'assainissement peut se faire par la construction et maintenance des infrastructures et le changement de comportements de la population vis à vis à la gestion de l'eau et des déchets. Finalement et pour la suite des travaux. Il serait souhaitable que les chercheurs et ingénieurs dans le domaine de l'eau et de l'assainissement approfondissent la thématique traitée afin qu'on ait une population saine et riche avec un développement durable.

Mots cles : Eau potable; Assainissement et Hygiène; Solutions Techniques; infrastructures; Développement.

LIST OF ABBREVIATIONS AND ACRONYMS

2iE: Institut International d'Ingénierie de l'Eau et de l'Environnement

ACF : Action Contre la Faim

AfDB : African Development Bank

AGIR: Global Alliance for Resilience Initiative

AWF : African Water Facility

ECHO: European Community Humanitarian aid Office

ECOWAS: Economic Community of West African States

EIA : Environmental Impact Assessment

IEM: Integrated Environmental Management

MDGs : Millennium Development Goals

MS : Micro Soft

MSF : Médecins Sans Frontières

PHAST: Participatory Hygiene and Sanitation Transformation

PRA: Participatory Rural Appraisal

PVC : Polyvinyl chloride

SDGs : Sustainable Development Goals

UNICEF: United Nation Children's Fund

USAID : United States Agency for International Development

VIP : Ventilated Improved Pit

WASH : Water, Sanitation and Hygiene

WAWASH : West Africa Water Supply, Sanitation and Hygiene

WC : Water Closet

WHO : World Health Organisation

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I. GENERAL INTRODUCTION

I.1 INTRODUCTION

The level of development of any community is generally observed in its healthy and wealthy population whose basic facilities or sevices create good conditions of living. For example if there are good water and sanitation facilities (good water sources, water points, water distribution networks, wastewater disposals,..) in a country, the medical fees should be widely reduced and the population is almost free from water, sanitation and hygiene (WASH) related diseases and then they should work for a sustainable development. Access to water and sanitation is one of the major challenges for the 21st century. According to WHO (2004), 1.1 billion people across the world do not have access to safe water and 2.4 billion people do not have access to basic sanitation facilities. As a consequence every year around 4 million people, the majority of who are children, die from water and sanitation related diseases (ACF, 2005). Increasing the equitable access to and use of safe water and basic sanitation services and improved hygiene practices will reduce morbidity and mortality, improve health and education outcomes, and contribute much to the reduction of poverty and sustainable development.

As a seemingly dry region, the Sahalian Areas people have to work for a sustainable development according to the World visions and targets such as Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs). To reach this, WASH Engineers in collaboration with other Stakeholders in water and sanitation field, have to work hard in order to progress as fast as possible, as we are directly involved in this situation. The implementation and use of stable and safe WASH facilities/services is based on design (planning) and the consultation of beneficiaries for future good exploitation. In this project report, there is a review on documentations, stating the actual status of Sahel region and its technical problems in a view to come up with suitable solutions in water and sanitation sector.

I.2 PROBLEM STATEMENT

The Sahelian area is the region where there is a scarcity of open water bodies (lakes, rivers,), few months of rain during the whole year, deep groundwater (aquifer) and poor sanitation practices. This disastrous access to water and sanitation is due partly to a lack of infrastructure but also to poor management that creates waste, contamination and degradation of the environment (ACF, 2005). From this reason, there is a big number of people without sustainable access to safe drinking water and basic sanitation facilities or servises which are fundamental to human development and well-being in Sahel. They (Water and Sanitation) are not just goals in their own right but also critical to the achievement of other developmental objectives such as adequate nutrition, gender equality, education and the eradication of poverty. Access to safe water and sanitation is also a human right issue, as recognized in 2010 by the United Nations General Assembly (Progress on Sanitation and Drinking Water, 2015). The United Nations, the Non-Governmental Organizations, Academic Institutions are looking forward to successfully meet and address the water and sanitation challenges. Water, sanitation or hygiene activities/ facilities aim to reduce the environmental disease reservoirs and interrupt the transmission routes. Depending on the context, it means improving environmental hygiene and health by increased access to an adequate drinking water supply, a proper excreta disposal, run off and waste water disposal, collection and disposal of refuse and medical waste, effective vector control interventions and proper disposal of dead bodies (MSF, 2010).

By that, we can make life and dignity a reality for many people in dry Sahelian areas through sustainable water and sanitation facilities. This work aims to provide some technical solutions for better access to water and sanitation in dry Sahelian areas which is the zone extending from Sudan in the east to Senegal in the west, and separating the Sahara from the tropical regions of western and central Africa.

I.3. RESEARCH OBJECTIVES

I.3.1 MAIN OBJECTIVE

The main objective of this work is to propose technical solutions for better access to water and sanitation in dry sahelian areas. In summary, the main objective is structured as follows:

- Proposal of solutions for Water Access adapted in Sahel region such as rainwater reservoir, run off water pond, well and water borehole.

— Proposal of solutions for Sanitation and Hygiene Access adapted in Sahel region like excreta and wastewater management (pit latrine, septic tank,..), solid waste management (Reduction, Reuse, Recycling, dumping and landfill, Incineration, compost), public awareness (Sanitation and Hygiene promotion, Environment protection,…)

I.3.2 SPECIFIC OBJECTIVE

The specific objective of the work is:

- ✓ To deepen the knowledge gained during the lecturing of Humanitarian WASH courses and relate them to the practical or professional application good hygiene practices (the provision of safe drinking water, the reduction of environmental health risks, creation of the conditions that allow people to live with good health, dignity, comfort and security).
- ✓ To be familiar in proposing and choice of WASH technical solutions so that it becomes easier to select an adequate design for a dry region or any other area.
- ✓ To come up with possible technical solutions in adressing the problems of water and sanitation.

I.4. METHODOLOGY

To achieve the intended purpose, the following methodology has been selected based on the available means and techniques:

- A literature review of the bibliographical references and webgraphy relating to the subject (Water and Sanitation) were conducted.
- Consultation with the professionals in WASH sector were involved to achieve the research project goals.
- To carry out this project, certain materials were needed. Material were car for transport, telephone for communicating with any contributer, computer, camera, notebooks, pens…

I.5. STRUCTURE OF THE RESEARCH

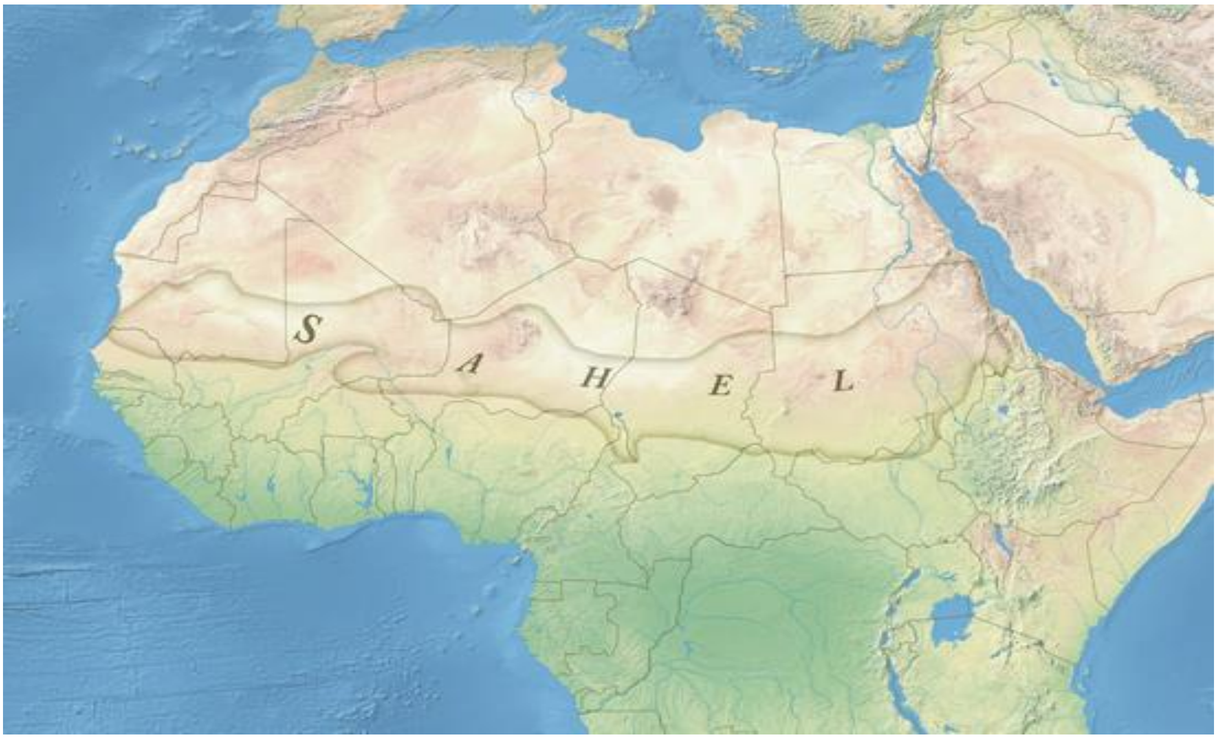
This research project is structured as follows:

- Chap I: General introduction
- Chap II: General presentation of Sahel Region
- Chap III: Overview of Water, Sanitation and Hygiene (WASH) Sector
- Chap IV: Discussion of Water and Sanitation Access issues
- Chap V: Problem-solution analysis
- Chap VI: Conclusions and recommendations
- Limitations
- References
- Appendices

II. GENERAL PRESENTATION OF SAHEL REGION

II.1. Geographical Situation

Sahel region is the zone extending from Sudan in the east to Senegal in the west, and separating the Sahara from the tropical regions of western and central Africa. This region also extends its boundaries on the countries of Mali, Burkina Faso, Mauritania, Chad and Niger. The following map gives a hint on the location where we can find Sahel in Africa :



Description	**English:** This is a map illustrating the Sahel region of Africa. Derived from Natural Earth data. Projection: Lambert Conformal Conic, CM: 14E, SP: 10N, 25N
Date	31 August 2015
Source	Natural Earth Data --> ArcMap --> Illustrator & Photoshop
Author	Munion

Figure 1 **:** Map illustrating the Sahel region of Africa

II.2. CLIMATE, RAINFALL AND ECONOMIC SITUATION

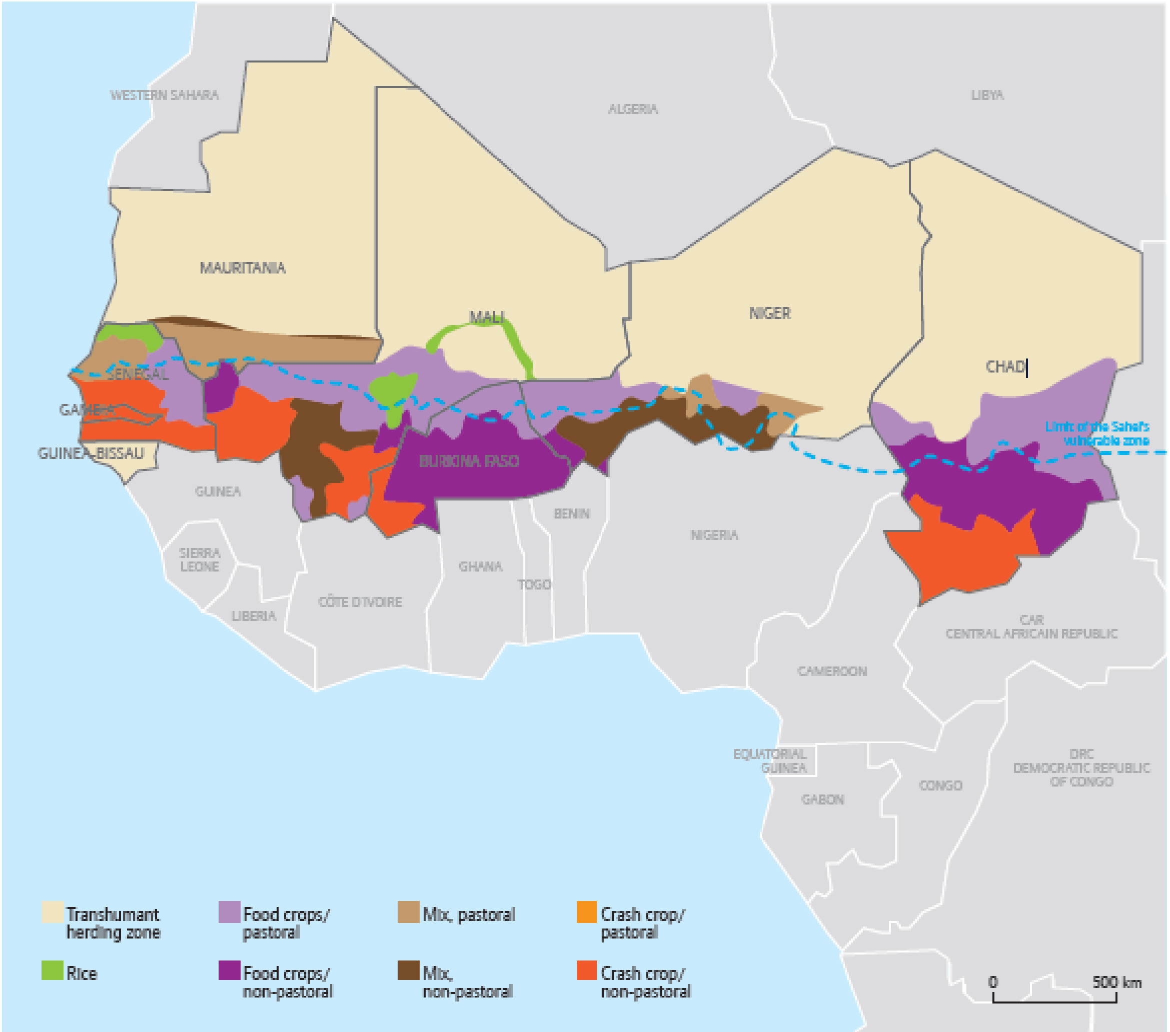
The Sahel region suffers from low and erratic rainfall, long droughts, and occasional heavy rains and flooding which significantly affect livestock and crop yields. In addition, over the last 30 years, the average rainfall has decreased across the whole of the southern Sahelian region, increasing the difficulties for those who survive on rain-fed agriculture and pasture (see Figure 1) **(Natasha and Al…, 2014 in ECOWAS 2005)**. As a result, food security in this fragile environment has long been a critical issue. In 2014, 20 million people in the Sahel are 'food insecure': lacking access to a sufficient quantity of affordable, nutritious food (Natasha and Al…, 2014 in ECHO 2014). The rate of Global Acute Malnutrition3 in the Sahel has now exceeded the 'alert threshold' of 10% of the population for more than 10 years (Natasha and Al…, 2014 in AGIR 2013) and in 2011, between 40-45% of children under 5 years old in the Sahel lagged behind normal growth rates (Natasha and Al…, 2014 in AGIR 2013). This negative picture masks significant positive change recently in the region: although absolute levels are still very high, all four focus countries in this report demonstrated a very significant reduction in poverty over the last 15 years.

Africa is the world's second fastest-growing region, with extreme poverty declining fast (Natasha and Al…, 2014 in MDG Report 2013). However the absolute number of poor has increased in Africa over this time (1990-2010) from 290m to 414m, in part due to high population growth (Natasha and Al…, 2014 in MDG 2013). Both Mali and Niger show a startling reduction in the proportion of people suffering from hunger during the last 20 years (see Table 1).

Table 1**:** Millennium Development Goal Progress on Goal 1 for 4 Sahelian Countries

country	**Poverty levels: Proportion living at below USD1.25 (ppp)per day - start**		**Hunger levels: Proportion living below minimum level of dietary energy consumption**	
	Initial	Most recent	Initial	Most recent
Burkina Faso	71.2% (1994)	44.6% (2009)	22.9% (1991)	25.0% (2012)
Mali	86.1% (1994)	50.4% (2010)	24.9% (1991)	7.3% (2012)
Niger	72.8% (1992)	43.6% (2008)	35.5% (1991)	13.9% (2012)
Senegal	65.8% (1991)	29.6% (2011)	22.0% (1991)	21.6% (2012)

Source (2013) MDG Country Snapshots: http://mdgs.un.org/unsd/mdg/Host.aspx?Content=Data/snapshots.htm



Source: ECOWAS-SWAC/OECD CRA (2005)

Figure 2**:** livestock and farming zones in Sahel

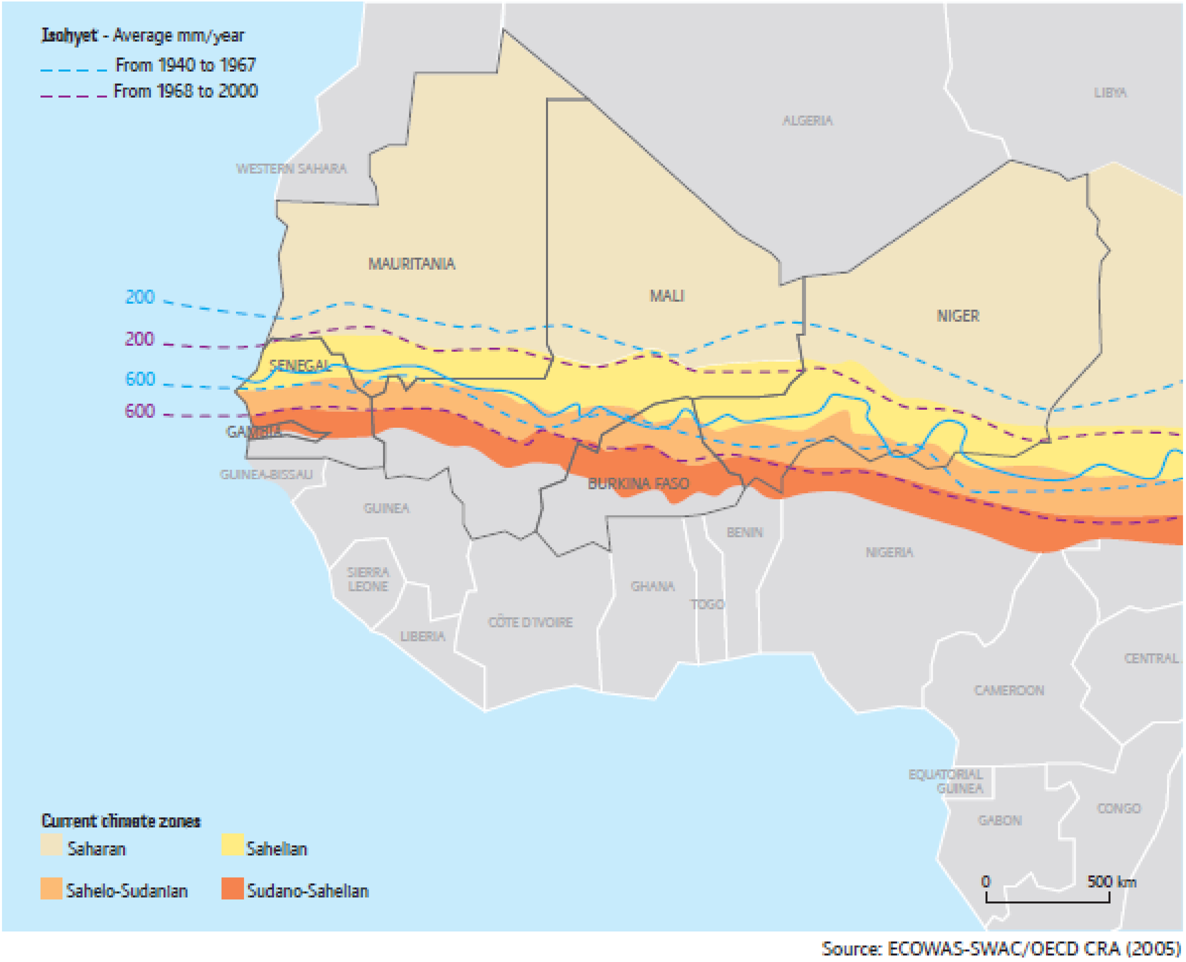


Figure 3**:** Rainfall and climate zones in Sahelian countries in West Africa

III. OVERVIEW OF WATER, SANITATION AND HYGIENE (WASH) SECTOR

III.1. INTRODUCTION TO WATER AND SANITATION

Water and sanitation services are critical determinants for assessing the level of living style for any population. People are directly affected by poor facilities as they are generally much more susceptible to illness and death from disease, which to a large extent are related to inadequate sanitation, inadequate water supplies and inability to maintain good hygiene.

The most significant of these diseases are diarrhoeal and infectious diseases transmitted by the faeco-oral route (see Appendix 7). Other water and sanitation related diseases include those carried by vectors (see Appendix 5) associated with solid waste and water. The term ‘sanitation’, throughout the Sphere Handbook, refers to excreta disposal, vector control, solid waste disposal and drainage (Sphere Handbook, 2011). This chapter is mainly focused on the review of the process of designing better access to water and sanitation solutions in general. Through this chapter, we are going talk about access of water source in general, introduce and develop different techniques of rainwater harvesting, surface and groundwater exploitation, excreta and waste management, public awareness through the education based on sanitation and hygiene promotion.

III.2. WATER SOURCE ACCESS

The sources of water are limited with low availability to provide clean drinking water to the all African population. Surface water sources are often highly polluted, and infrastructure to pipe water from fresh, clean sources to arid or semi arid areas is too expensive to implement. Groundwater is the best resource to tap to provide clean water to the majority of areas in Africa, especially rural Africa, and groundwater has the benefit of being naturally protected from bacterial contamination and is a reliable source during droughts.

However, the high costs associated with drilling for water, and the technical challenges in finding sources that are large enough to serve the population in need, present challenges that limit tapping the resource. Groundwater is not a fail-safe resource, either, when it comes to providing clean water. There may be contamination of the water with heavy metals, and bacteria may be introduced by leaking septic systems or contaminated wells. For these reasons, it is important that groundwater be monitored frequently, which is expensive and requires advanced techniques that may not be present in rural areas (Awuah, et al., 2009).

III.3. RAINWATER HARVESTING

Rainwater harvesting is to capture the water of rain from building roofs and other catchment areas such as paved or cemented area in open ground space. The systems for Rainwater harvesting are often installed at the building level, collecting water from houses or public buildings such as schools or hospitals. It is difficult to maintain the quality of rainwater, so it is often used for other purposes when there is a suitable alternative supply of drinking water (ACF, 2005). The harvesting of rainwater is a common practice in many countries. Generally, two types of catchment systems are used. **Artificial** and **land surface** catchments are used to collect rain. At a domestic level, this surface is generally provided by the roof of the house: gutters collect the rainwater and guide it towards storage vessels (jars, barrels or tanks). In the south of Madagascar and in Haiti, there are collective catchment surfaces made of reinforced concrete slabs laid on the ground, with a slope that allows the water to flow down to underground reservoirs. The bacteriological quality of such water depends on the cleanliness of the collection surface, channels and tank, and on storage and drawing methods

The harvesting of rainwater is also carried out directly: in Cambodia and Myanmar, domestic or collective ponds are dug. Rain fills up those ponds, which can be permanent or temporary, but are generally muddy and biologically contaminated (ACF, 2005).

Rainwater in non industrialized and non urban areas presents normally good quality characteristics. Although its availability along the seasons is generally important, rainwater harvesting can be interesting to cover the whole water demand, or complement other water sources that are insufficient in quantity and / or quality. Rainwater can be collected from any clean surface, with catchments being used most often. The rainwater is then transfered to a tank via gutters. The contamination of harvested rainwater comes primarily from the first rains, rinsing away the accumulated dirt on the roof. Correct techniques of rainwater harvesting will remove this contamination first before the water is used (MSF, 2010).

Some methods to collect rainwater like the use of Rain Barrels, Dry and Wet Systems are presented in the following:

Rain Barrels method

This method is the most common and one that many people are familiar with. This involves installing a barrel at a gutter downspout to collect rainwater.

The actual barrel may be a recycled barrel or a new commercially available rain barrel.

"Dry" System

This method is a variation of a rain barrel set-up, but it involves a larger storage volume. Essentially, the collection pipe "drys" after each rain event since it empties directly into the top of the tank.

"Wet" System

This method involves locating the collection pipes underground in order to connect multiple downspouts from different gutters. The rainwater will fill the underground piping and the water will rise in the vertical pipes until it spills into the tank. The downspouts and underground collection piping must have water-tight connections. The elevation of the tank inlet must be below the lowest gutter on the house.

The table 2 summarises rainwater harvesting methods, their advantages and desadvantages :

Table 2: Advantages and desadvantages rainwater harvesting methods

Method	**advantages**	**desadvantages**
Rain barrel	-Easily implemented by anyone at any residence -Barrels are readily available in your community or at various stores & websites -Barrels don't take up much space so they can fit into any situation	-Capacity is generally only 50 to 100 gallons (one gallon is between 4 to 5 liters) -Easily overflows and wastes collection opportunities
Dry system	-Can store a large amount of rainwater -Great for climates where rainfall happens with infrequent, larger storm events -Can be inexpensive to implement -Less complicated system so maintenance is easier	The storage tank must be located next to your house

Wet system	-The ability to collect from your entire collection surface -The ability to collect from multiple gutters and downspouts -The tank can be located away from your house	-More expensive to implement due to underground piping

(Source:http://www.watercache.com, innovative water solution)

Rainwater harvesting arrangement

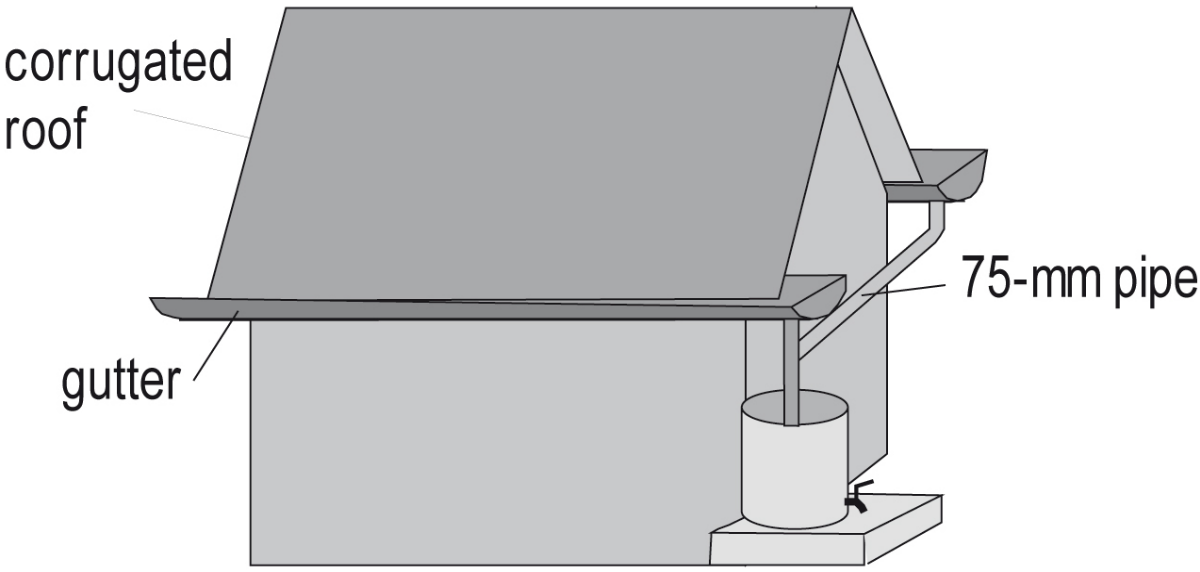


Figure 4**:** Harvesting of water from a roof. (ACF, 2005)

III.4. SURFACE WATER EXPLOITATION

Surface water comes in many forms, and methods of exploitation are very varied. Part of the rainwater that arrives on the ground runs off. Sometimes this water is intercepted by some man-made structure, especially in areas with a dry climate. For example, in a ***sahelian area***, runoff that concentrates at low points is retained by **a dam** and used for human and animal needs. These ponds or dams can be temporary or permanent, but they are generally muddy and polluted by fecal matter. They are difficult to protect, but being possibly the only available resource, they are also vital. Storage can be in underground reservoirs, which are called *birkad* in East

Africa (Ethiopia, Somalia). Animals do not have a direct access to the reserve, to protect it from contamination, and evaporation is reduced (ACF, 2005).

III.4.1. Types of ponds (Dams)

Two types of ponds exist: **'impluvium ponds'** and **'run-off ponds'**. Impluvium ponds are used in places where precipitation is high (humid tropical areas, e.g. South East Asia). These ponds do not have a catchment basin, but collect the rainwater that falls directly onto their surface. Water quality thus depends on the sanitary conditions of the pond (cleanness, presence of animals etc.). In this case, adequate design and construction (including the installation of features such as appropriate water-drawing structures), and water-point management can lead to satisfactory water quality, and the water can be used for domestic and drinking purposes.
Where precipitation is low, in the so-called arid and semi arid lands such as the Sahel, the Horn of Africa, the Kalahari etc., the ponds are located in low-lying areas and collect run-off water. Given all the opportunities for contamination during run-off, water quality is poor. On the other hand these ponds are mostly used in areas populated by pastoral communities and are mainly used for animal consumption. This also increases the risks of water contamination.
In these pastoral areas, ponds may be used by different clans or communities and are usually isolated from permanent settlements. Water-supply management cannot, therefore, be done on a regular basis and any sophisticated installations should be built only after analysing operation and maintenance constraints. In any case, the risk of water contamination remains high and treatment before consumption (by boiling, filtering etc.) is the best way to guarantee access to safe drinking water. The inhabitants generally should know how to build or rehabilitate ponds or rainwater reservoirs, but to optimize them and ensure longer service life, certain rules and construction parameters must be observed (ACF, 2005 and MSF, 2010).

III.4.2. Surfacewater quality and drainage

Water is an ideal host environment for many bacteria and insects, and stagnant waters are a factor in the transmission of diseases that are water-borne or water-based, or carried by water-related insect vectors. Stagnant water may result from the blockage of water flow, by the accumulation of rain water, or as a result of wastewater from water-supply and sanitation systems. Drainage systems are also necessary to control run-off after heavy rainfall, that can potentially damage infrastructure. The principle of drainage systems is to channel wastewater along natural slopes to transport it away from human habitation into a natural drainage system or artificial infiltration system.

Design and implementation of a drainage system :

Surface-water drainage systems should be planned after topographical studies to determine the slope of the terrain. The dimensions of the drainage system will be a function of the volume of water that it will carry, the design and construction constraints associated with urban, village or rural contexts, and the resources available. Bridges, or platforms, that allow people and vehicles to move over drainage channels need to be designed into any system.

The main activities during drainage construction include: the sizing and measurement of a drainage network (which must include an analysis of the intensity and the periodicity of rainfall), the actual construction and maintenance of the system (which must include community participation), the protection of the channel margins against erosion (e.g. by soil stabilisation through tree-planting).

Drainage channels can be dug manually or by machine. For manual digging, it is important to involve the community. Channels may or may not be covered or protected. Protection can be made with concrete or stone, and must be removable to facilitate maintenance operations.

Maintenance of the system must be done on a regular basis as an accumulation of materials such as dead vegetation, refuse and silt may obstruct the water flow, leading to overflows and an unsafe environment.

III.5. GROUNDWATER EXPLOITATION

Rocks capable of containing water and allowing it to flow easily are called aquifers. An aquifer is not necessarily a homogenous geological group: it can be composed of different rocks or strata. An aquifer has an area saturated with water, and sometimes a non-saturated area. It is spatially restricted by an impermeable rock at its base (the wall or substratum), sometimes by an impermeable rock above it (the roof), and by lateral restrictions.

The groundwater is all the water contained in the aquifer, generally supplied by useful precipitation (the fraction of precipitation that infiltrates and feeds the aquifer) and the infiltration of surface water (streams and lakes).

Aquifers are not static: part of the water leaves the aquifer in the form of springs, feeding surface water (streams, lakes, seas), by pumping, or by direct evaporation (Figure 5, 6&7).

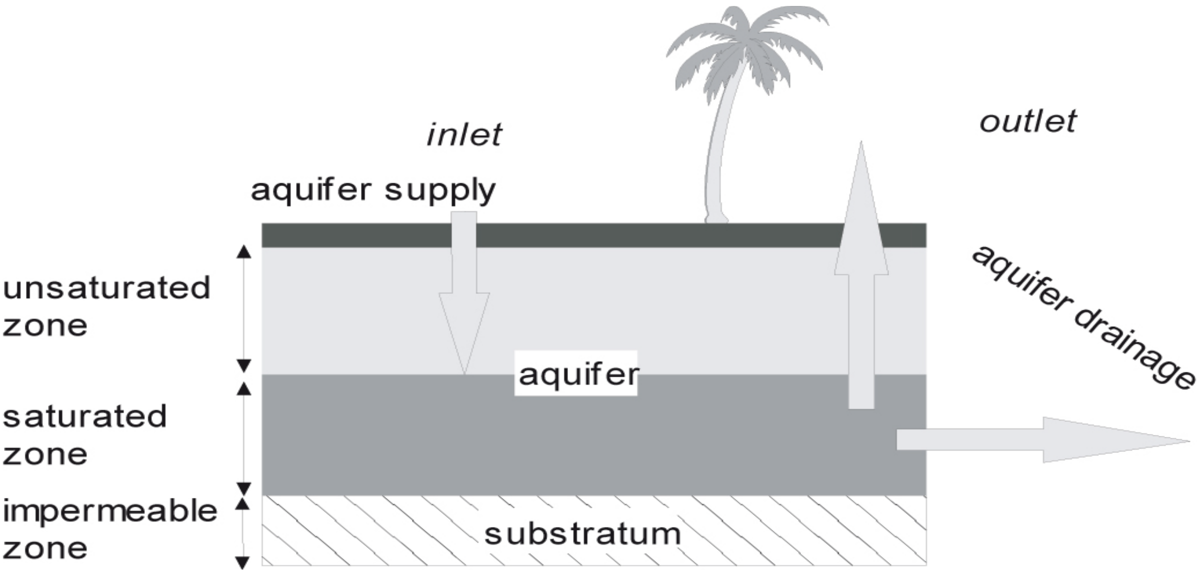


Figure 5**:** Storage and flow in an unconfined aquifer

The groundwater can be accessed by means of springs (the water coming on the surface naturally under pressure), wells or boreholes dug in the ground rock and sometime advanced expertise before the implementation.

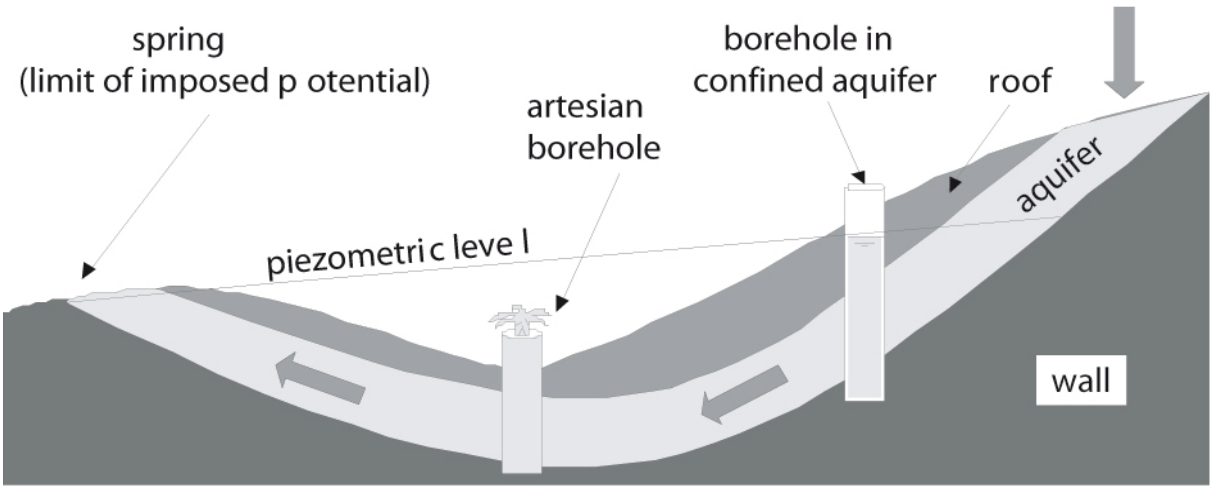


Figure 6**:** Confined acquifer (ACF, 2005)

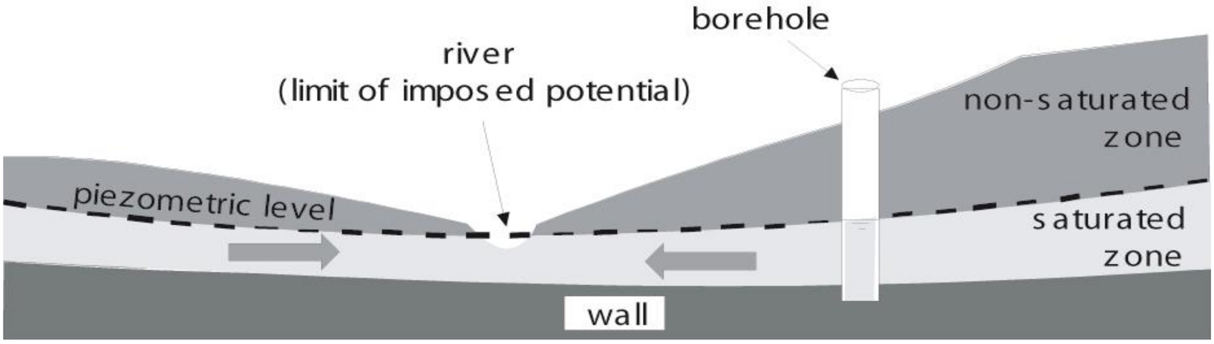


Figure 7**:** Unconfined acquifer (ACF, 2005)

III.5.1. Well and Borehole

A well is usually dug manually to reach an aquifer situated at some depth below the ground. Both depth less than 20m and diameter 1-2m of the well vary according to local conditions and it does not need specialized to be construted Throughout history, people have dug wells to ensure a permanent water source. *Borehole* is a narrow-diameter tube drilled into the ground at a controlled angle (usually vertical). This is a common type of water source used on rural water supply with depth between 20 and 100 m and more, its diameter can vary between 100 and 300 mm.

Modern wells

Traditional wells are rarely lined, or only for part of the depth, usually with wood, so that the well must be regularly re-dug and rebuilt. As they are simple holes in the ground, these wells are rarely protected from surface pollution (contaminated water). Some wells are constructed using stone or brick. The best examples are the pastoral wells constructed during colonial times in the Sahara, several dozen metres deep, and some 2 to 3 m across. Wells of more modern type, which are the subject of this chapter, are lined in reinforced concrete for the whole of their depth, from the surface to the intake section. Construction techniques are tried and tested, and pastoral wells can reach 100 m in depth. They have a width of 2 m to be able to exploit Sahelian aquifers, and they are open and often equipped with several pulleys. Significant quantities of water are extracted (using animal power) to supply herds of animals. Village wells are more modest, running to depths of 20 to 30 m, and equipped with manual water-drawing systems (scoops, pulleys, winches or handpumps) (ACF, 2005).

Combined well

In certain sedimentary basins, there are captive aquifers covered by impermeable levels situated several dozens or even hundreds of metres in depth, but with static levels close to the surface. These aquifers, reached by boreholes, are exploited from wells whose depth varies with the static level. This facilitates drawing by hand. The intercalated continental aquifer levels of the Sahara (Mali, Niger) are often of this type, and do not need pumps, which would be difficult to manage in this context (nomadic population).

These wells act like underground, water-tight storage tanks. They are dug next to the borehole or around it, and connected to it with a horizontal tube welded to the casing, fitted with an open stop-valve to the wellcistern or with a ferrule strap.

This type of well provides a particularly useful water storage solution for the exploitation of aquifers with poor flows. The Figure 8 is an example of a combined well arrangement and was constructed by ACF in Asia (ACF, 2005). The enormous advantage of the well in relation to the borehole is its storage capacity (related to its diameter) and the possibility of manual water drawing. Its permanence makes it very ***suitable for the conditions of the Sudan-Sahelian region***, and other isolated or particularly remote regions. The cost of construction is considerable, so it should be well built and durable (ACF, 2005). The figures and ……show how the protection of wells and or water borehole should be designed.

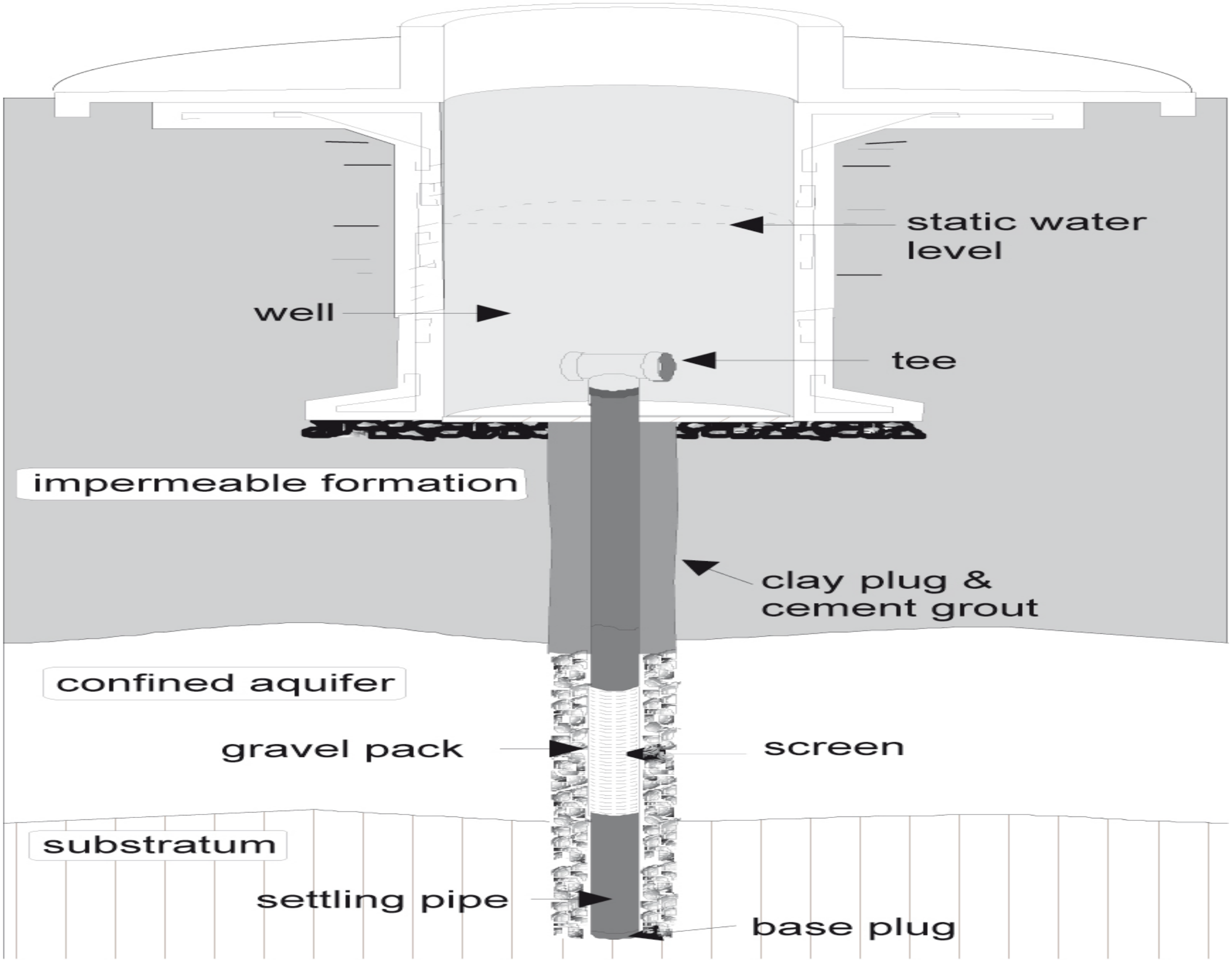


Figure 8**:** Central combined well (source : ACF, Cambodia, 1998).

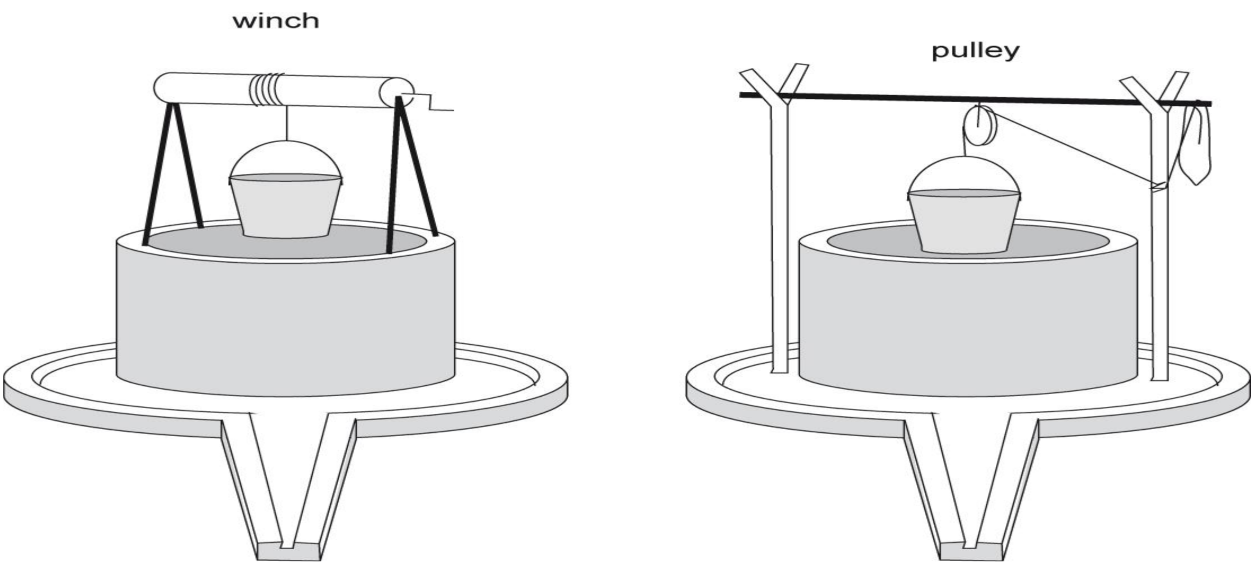


Figure 9**:** Manual water drawing (ACF, 2005)

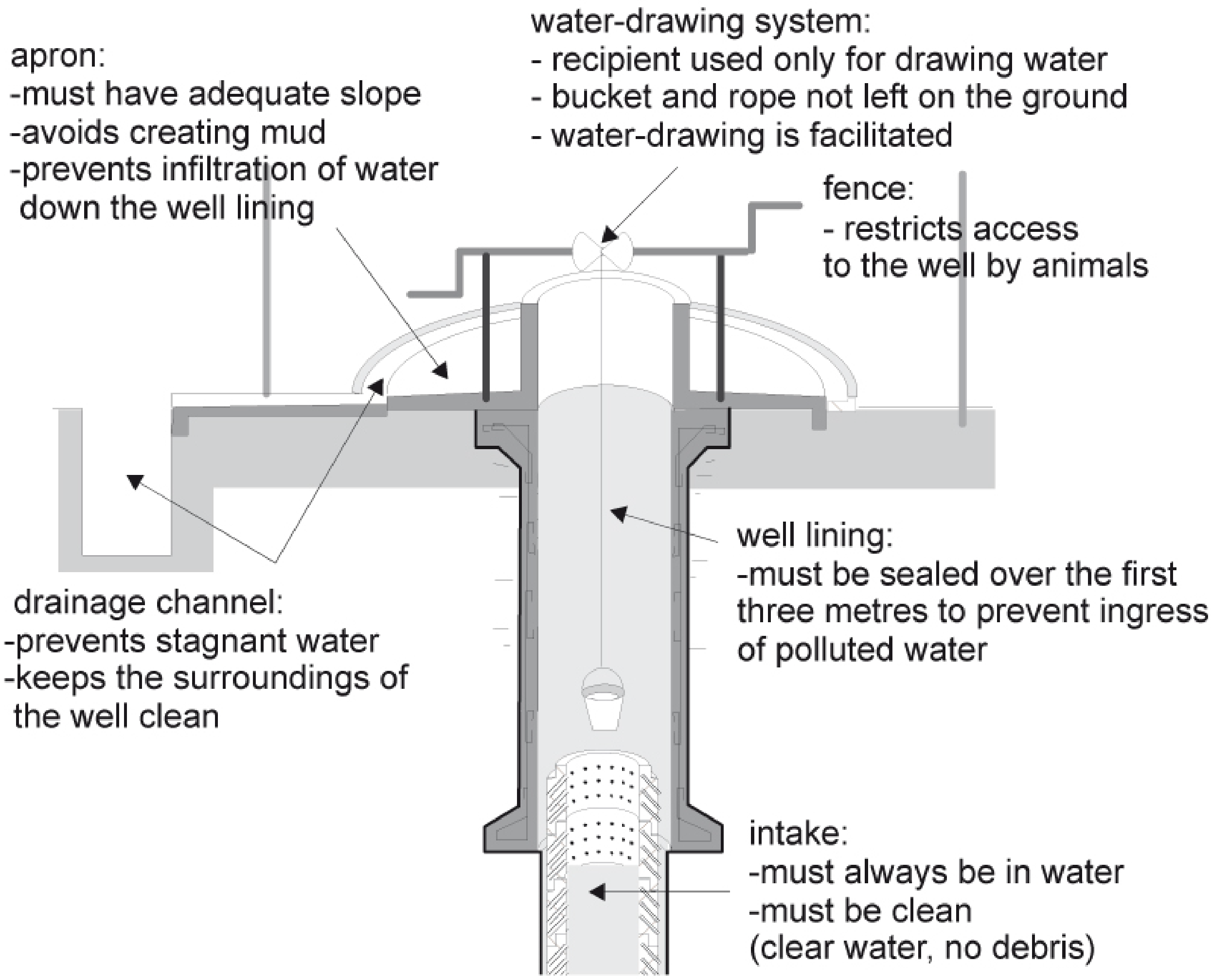


Figure 10**:** Protecting a well from pollution (ACF, 2005)

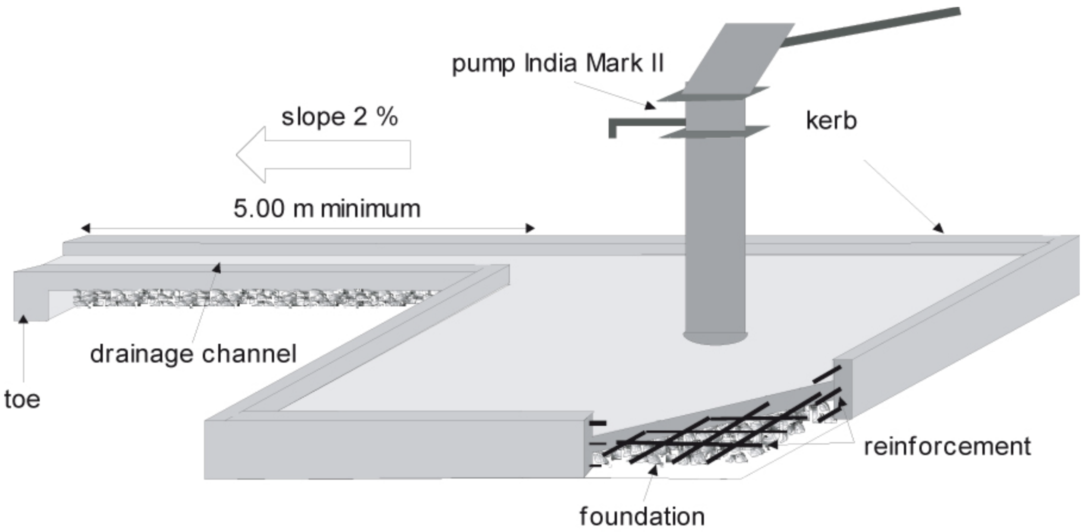


Figure 11**:** Borehole surface works (ACF, Kampala, Uganda, 1996).

In any design and implementation of a water well or a borehole, the protection of the structure should be taken into account (see figures 9, 10 and 11).

III.5.2 Water Pumps

To drow the water from a borehole, we need a system able to fulfill this task economically and with less or without environmental pollution. In this situation Renewable energy pumps (Solar powered pump, Wind mills,…) are most preferable in addition to hand pumps or manually activated pumps. Electricity and fuel (for generators) may be used but they are not economically sound and can contibute to the environmental pollution.

Solar pump : Nowadays, solar pumping technology is widely available from various manufacturers. It can be useful for water supply to a medium-size village. However, flows and TMH remain limited (a maximum of 100 m3/day/100 m). Also, the area of the solar panels to be installed quickly becomes significant, with consequent increases in cost. Maintenance of these installations must be considered under the same terms as that of a conventional installation, even if the running cost is very low: it is necessary to ensure the availability of spares and the training of technicians for this method. Turning to solar energy must not lead to false ideas about the cost of the water and maintenance of the installation (ACF, 2005).

Hand pumps : are normally used for boreholes and wells. They allow wells to be sealed against contamination and, in many cases, may increase the amount of water lifted.
Most hand pumps are volumetric pumps with a submerged piston, controlled by a mechanical linkage or a hydraulic one (system developed by A. Vergnet). Some of them can pump water to a height of more than 60 m.Several types of durable hand pump have been developed to meet field conditions, especially intensive use. The choice is carried out on the basis of technical and socio-economic criteria.

Main types of hand pump

Hand pumps are classified according to their installation depth (see Appendix 2) **suction pumps** for dynamic levels less than 7 m; **lift pumps** for dynamic levels greater than 7 m; **pumps adapted** to great pumping depths (> than 35 m). Vergnet and Monolift pumps also have the capacity of delivering water to elevated tanks (this requires pump-head sealing).
The working flows of hand pumps vary depending on the installation depth and the type of pump. For example: **Aquadev pump** installed at 15 m: discharge of 1.4 to 1.8 m3/h; **VN6 suction pump** at 6 m: 1.5 to 1.8 m3/h and **HPV 60 Vergnet pump** at 35 m: 1 m3/h.
Mean flows, depending on pumping rate (strokes per minute), are given by the manufacturers. (ACF, 2005).

III.5.3. Groundwater quality

Groundwater has a reputation for being of good quality for human consumption. Biological, and especially microbiological contamination risk of this resource is extremely limited. However, the presence of mineral toxicity (natural pollution such as arsenic or fluorine) may occur, potentially leading to chronic health problems. When this type of natural pollution risk exists, rain or surface water become an alternative resource. Groundwater is generally less sensitive to various types of pollution than surface water (except in fractured contexts and karsts) (ACF, 2005).

III.6. WASTE MANAGEMENT

The general objective of waste management is to control and reduce the pollution of environment (surface/ ground water, air, plants, animals, men) due to poor waste management. Waste may be solid (refuse, feces), liquid (waste water) or gases according to its physical states and it can be classified according to the source of production as Excreta (human or animal fecal matter), Industrial wastes produced by industries, medical wastes, hazardous wastes, demolition…

Various methods are employed to deal with the huge amount of waste that is produced in the world. The methods employed by different communities vary according to their unique needs, and economic and environmental conditions. However, the five primary options are: source reduction, recycling, composting, landfilling, and waste to energy (combustion or incineration) (James D. Englehardt et all.., 2000 in Keep America Beautiful Inc., 1996). In the following, we are going to deal with waste management options.

III.6.1. Excreta disposal

Safe excreta disposal is of paramount importance for health and welfare and also for the social and environmental effects it may have in the communities involved (WHO, 1992).

Excreta-disposal systems may be classified according to the following criteria :

a. Final excreta-disposal site

– On-plot systems: where the disposal site for excreta is close to the home, such as latrines and septic tanks.

– Off-plot systems: where excreta is collected from the home and transported elsewhere to be treated or disposed of. The sewerage system is the most important example of this.

b. Necessity of water for operation

– Dry systems: do not require water for use, including simple pit latrines, ventilated improved pit (VIP) latrines and composting latrines.

– Systems using water: where the system requires water for operation, including flush toilets connected to septic tanks or sewerage systems. The selection of an appropriate system is based on technical, cultural, economic and institutional criteria (ACF, 2005).

Types of Excreta disposal facilities

Defecation in open areas

People defecate in open areas where there are no, or insufficient, latrines or where latrines present are not used. These open areas may be specific places that are widely accepted by the community as areas of defecation, such as refuse piles or under trees, and may be found inside or outside the living area of the community (ACF, 2005). Open defecation encourages flies,

which spread faeces-related diseases. In moist ground the larvae of intestinal worms develop, and faeces and larvae may be carried by people and animals. Surface water run-off from places where people have defecated results in water pollution.
In view of the health hazards created and the degradation of the environment, open defecation should not be tolerated in villages and other built-up areas. There are better options available that confine excreta in such a way that the cycle of reinfection from excrete-related diseases is broken (WHO, 1992).

Dry latrines

Shallow pit

People working on farms may dig a small hole each time they defecate and then cover the faeces with soil. This is sometimes known as the "cat" method. Pits about 300 mm deep may be used for several weeks. Excavated soil is heaped beside the pit and some is put over the faeces after each use. Decomposition in shallow pits is rapid because of the large bacterial population in the topsoil, but flies breed in large numbers and hookworm larvae spread around the holes. Hookworm larvae can migrate upwards from excrete buried less than in deep, to penetrate the soles of the feet of subsequent users (WHO, 1992).

Table 3**:** Advantages and desadvantages of shalow latrine

Advantages	**Desadvantages**
No cost	Considerable fly nuisance
Benefit to farmers as fertilizer	Spread of hookworm larvae

SIMPLE PIT LATRINE

The most common excreta-disposal system in many parts of the world is the simple pit latrine used by families (Figure12). This type of latrine is a simple, rapid and economical means of excreta disposal. It is often used as the first step to improve environmental sanitation (ACF, 2005). It may be of shallow (less or equal to two meters deep) or deep (greater than four meters deep) pit. The latter latrine type is called borehole latrine.

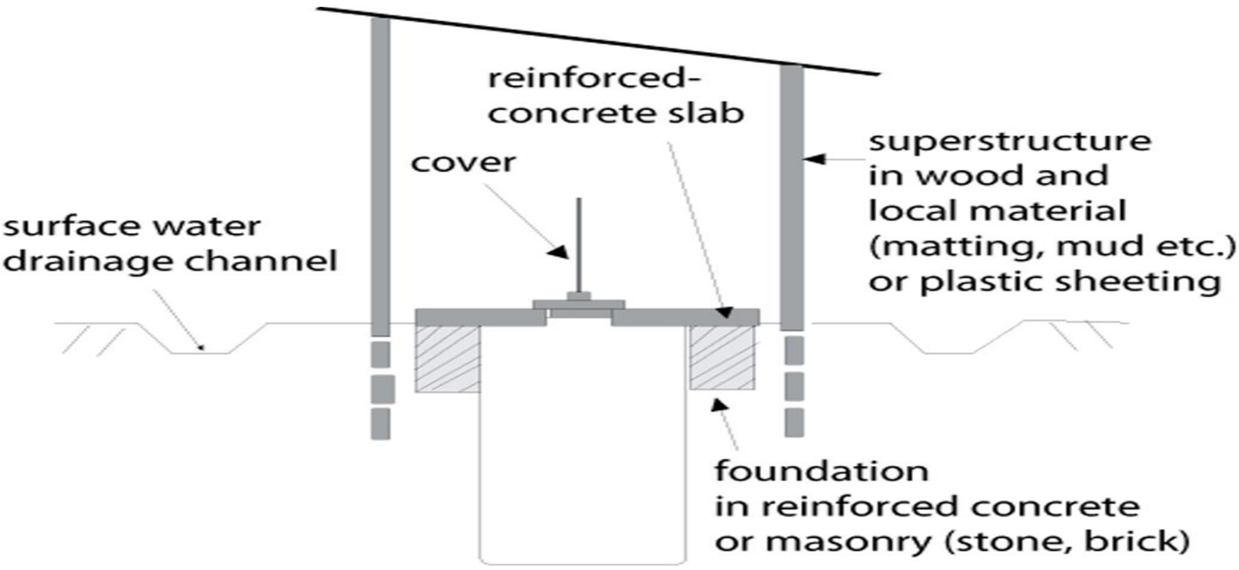


Figure 12**:** Simple pit latrine.

Table 4: Advantages and desadvantages of simple pit latrine (source: ACF 2005)

Advantages	**Desadvantages**
Can be excavated quickly if boring equipment is availabe	Sides liable to be fouled, with consequently nuisance
Suitable for short term use	Short life owing to small cross sectional area
	Great risk of ground water pollution owing to depth of hole

VENTILATED IMPROVED PIT (VIP) LATRINE

Fly and odour nuisance may be substantially reduced if the pit is ventilated by a pipe extending above the latrine roof, with fly-proof netting across the top. The inside of the superstructure is kept dark. Such latrines are known as ventilated improved pit (VIP) latrines (WHO, 1992).

The VIP latrine (Figure 13) is an improved version of the simple pit latrine, and includes several advantages:

– It reduces smells, which makes the latrine more acceptable to users (if the latrine has an unpleasant smell, the promotion of further latrine construction and use is difficult);

– It allows the control of flies, which can be a vector of disease.

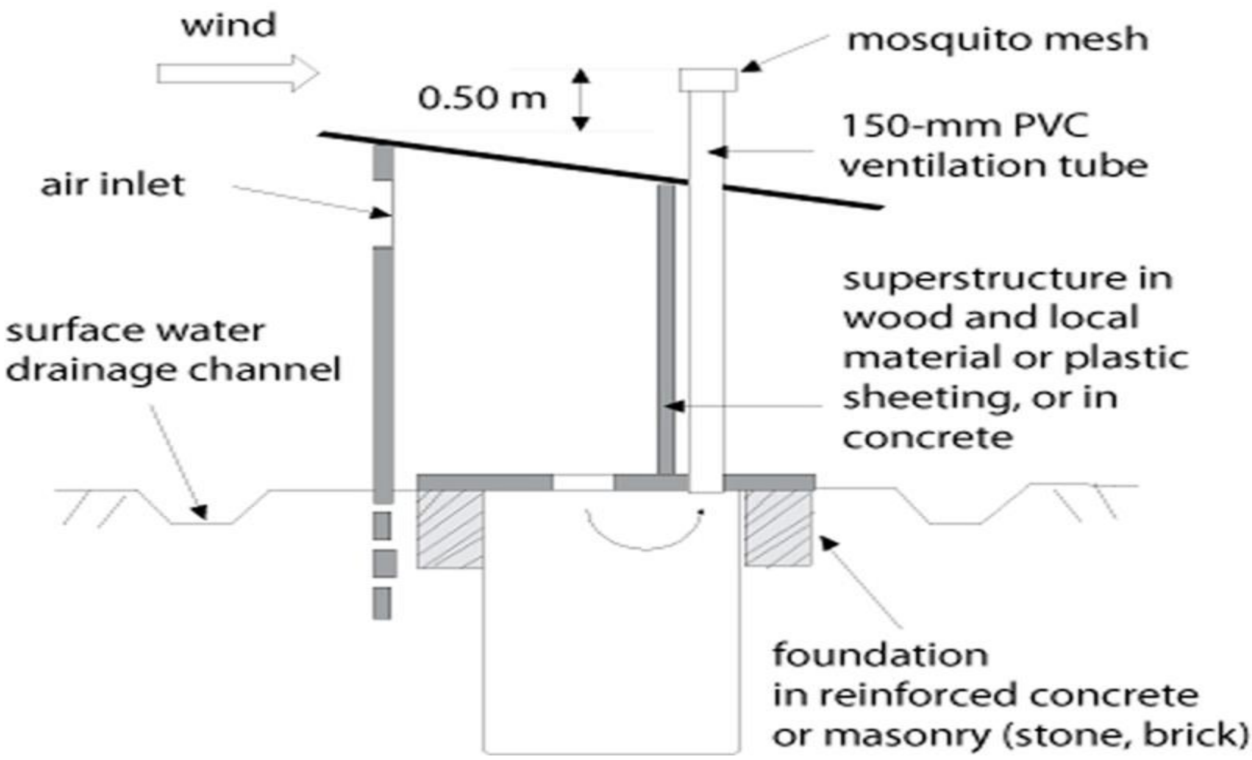


Figure 13: Ventilated Improved Pit (VIP).

Table 5: Advantages and desadvantages of VIP latrine (source: ACF 2005)

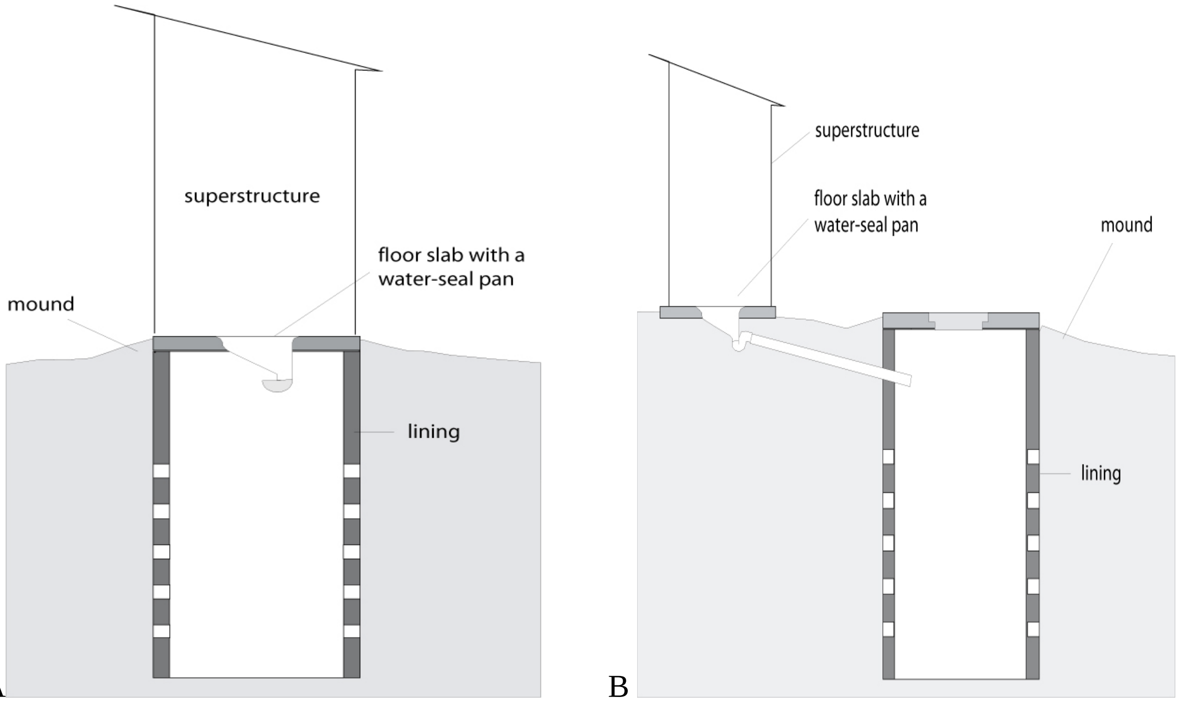
Advantages	Desadvantages
Low cost	Does not control mosquitos
Can be built by householder	Extra cost of providing vent pipe
Needs water for operation	Needs to keep interior dark
Easily understood	
Control of flies	
Absence of smell in latrine	

Pour-flush latrines

A latrine may be fitted with a trap providing a water seal, which is cleared of faeces by pouring in sufficient quantities of water to wash the solids into the pit and replenish the water seal. A water seal prevents flies, mosquitos and odours reaching the latrine from the pit. The pit may be offset from the latrine by providing a short length of pipe or covered channel from the pan to the pit. The pan of an offset pour flush latrine is supported by the ground and the latrine may be within or attached to a house (WHO, 1992).

The pour-flush latrine is the most effective system to avoid bad smells and the proliferation of flies and mosquitoes, by keeping the pit isolated from the exterior. This latrine includes a water seal at the extremity of the pan (or bowl) in which the excreta is deposited. The seal remains full of water and guarantees that the pit is isolated.

This system requires water on a permanent basis, both for cleaning the pan and for maintaining the seal (between 1.5 and 2 litres minimum for each flush). Therefore, this solution is only applicable where the availability of water is guaranteed (ACF, 2005).



A B

Figure 14**:** Latrines with water seal. A: set on top of the pit. B: with an off-set pit.

*Table 6***:** Advantages and desadvantages of Pour-flush latrine (source : ACF 2005)

Advantages	**Desadvantages**
Low cost	A liable (even if limited) water supply must be available
Control of flies and mosquitos	Unsuitable where solid anal cleansing material is used
Absence of smell in latrine	Contente of pit not visible
Offset type	Gives users the convenience of a WC
Pan supported by ground	Can be upgraded by connection to sewer when sewerage becomes available
Latrine can be in house	

Single or double pit

In rural and low-density urban areas, the usual practice is to dig a second pit when the one in use is full to within half a metre of the slab. If the superstructure and slab are light and prefabricated they can be moved to a new pit. Otherwise a new superstructure and slab have to be constructed. The first pit is then filled up with soil. After two years, faeces in the first pit will have completely decomposed and even the most persistent pathogens will have been destroyed. When another pit is required the contents of the first pit can be dug out (it is easier to dig than undisturbed soil) and the pit can be used again. The contents of the pit may be used as a soil conditioner. Alternatively, two lined pits may be constructed, each large enough to take an accumulation of faecal solids over a period of two years or more. One pit is used until it is full, and then the second pit is used until that too is full, by which time the contents of the first pit can be removed and used as a fertilizer with no danger to health. The first pit can then be used again (WHO, 1992).

Advantages of double pits:

- Once constructed the pits are more or less permanent
- Easy removal of solids from the pits as they are shallow
- Pit contents can be safely used as a soil conditioner alter 2 years, without treatmen

SEPTIC TANK

The septic tank is a waterproof underground tank that receives wastewater ('black-water' from toilets and / or 'grey-water' from cooking, bathing and laundry). It is the optimal on-site solution for toilets that function with water (Figure 15).

The septic tank comprises two chambers that are filled by wastewater that is transported via a pipe or channel, or falls directly from the latrine water seal. The wastewater is a separated into sludge, liquid and scum within the septic tank, and this effluent undergoes different chemical and physical transformations before part of it exits the tank. Even if the efficiency of the removal of suspended solids is good, the effluent will still contain a high concentration of pathogens and it is necessary to dispose it in a safe manner.

Effluent can be disposed of by:

– direct infiltration in the ground, with discharge into soakaway pits or trenches;

– recycling for agricultural uses after a pre-treatment process;

– a sewerage system that collects and treats effluent, where infiltration is not effective or where there is a risk of groundwater contamination (ACF, 2005).

Advantages:

- ✓ Gives the users the convenience of a WC

Disadvantages:

- ✓ High cost
- ✓ Reliable and ample piped water required
- ✓ Only suitable for low-density housing
- ✓ Regular dislodging required and sludge needs careful handling
- ✓ Permeable soil required

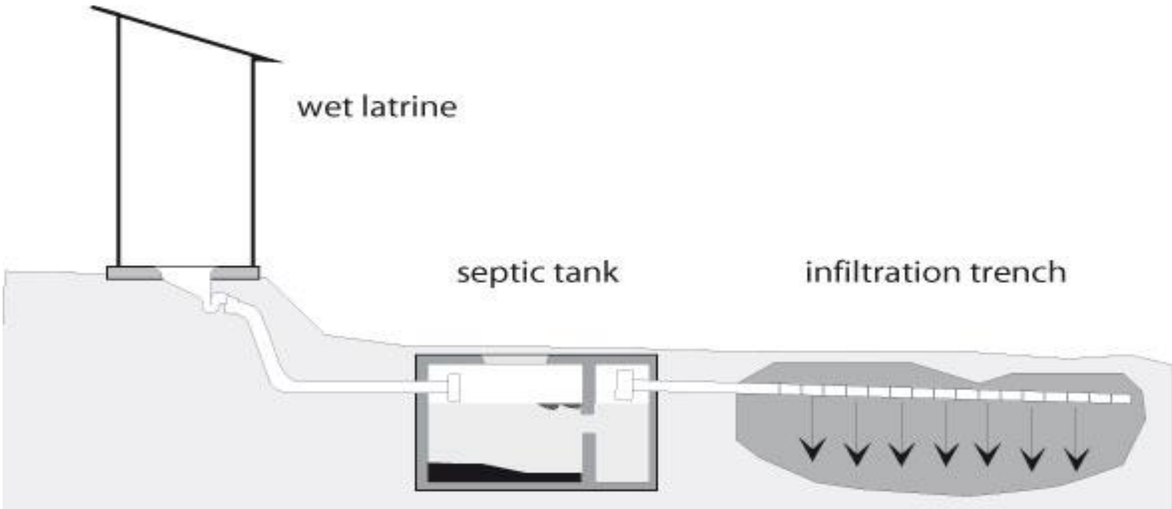


Figure 15: General view of wet toilet, septic tank and infiltration system.

AQUA-PRIVY

The aqua privy is a variation of a septic tank that has only one chamber. It consists of a watertight tank placed immediately below the latrine (Figure 16). Excreta falls directly into the tank via a pipe which is submerged in the liquid in the tank, forming a water seal that prevents flies and mosquitoes from escaping, and preventing smells. The level of liquid in the chamber must be kept stable for anaerobic digestion to take place. The tank functions in a similar way to a septic tank. The effluent from the tank normally infiltrates into the soil via a soakaway pit. The regular removal of sludge from the tank is essential for it to function correctly. For this purpose, it must be possible to open the lid of the tank. In some cases, the installation of a ventilation pipe, covered with mosquito mesh, is recommended in order to evacuate gases and minimise smells. The tank should have a volume of at least 1 m3 in order to avoid turbulence that prevents sludge sedimentation (ACF, 2005).

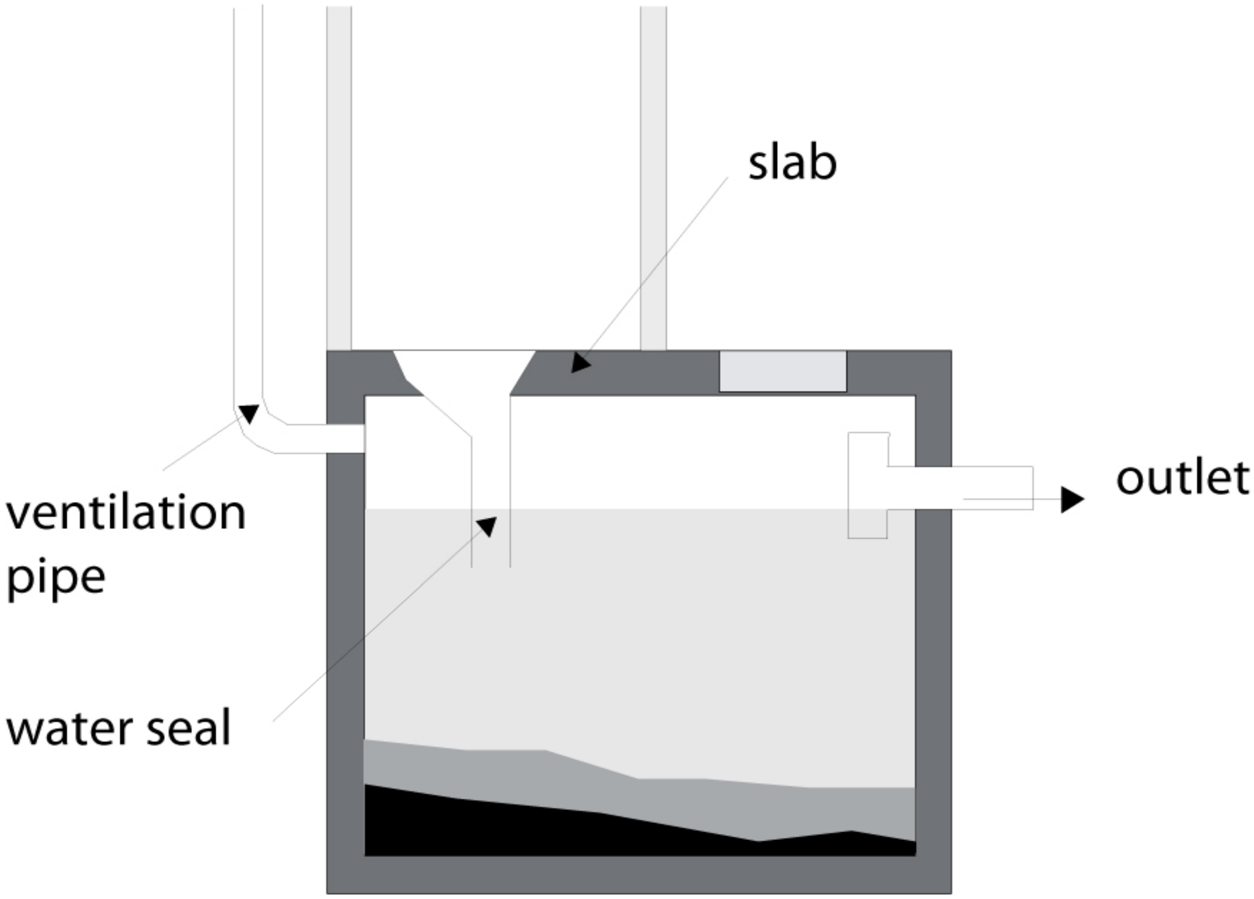


Figure 16**:** Aqua-Privy.

The comparison of simple, VIP and pour flush latrines by refering to the advantages and desadvantages may be found in **Appendix 6** for more information.

Reuse of effluent from septic tank

Wastewater is too valuable to be thrown away in semi-arid and arid areas, and may be reused for farming (or to raise fish). The use of wastewater for irrigation improves crop production, as it provides both moisture and nutrients (mainly nitrogen and phosphorous) that are beneficial for plants. However, wastewater should be treated to eliminate or at least reduce the level of pathogenic contamination that poses human health risks. WHO recommends that for irrigation, except for those vegetables that are eaten without cooking, which should not be irrigated with wastewater, the treated wastewater should not contain more than one nematode egg per litre and no more than 1 000 faecal coliforms per 100 ml (ACF, 2005).

Composting latrine

In this latrine, excrete fall into a watertight tank to which ash or vegetable matter is added. If the moisture content and chemical balance are controlled, the mixture will decompose to form a good soil conditioner in about four months. Pathogens are killed in the dry alkaline compost, which can be removed for application to the land as a fertilizer.

There are two types of composting latrine: in one, compost is produced continuously, and in the other, two containers are used to produce it in batches (WHO, 1992).

Composting latrines allow the reuse of excreta for agriculture and this system has advantages and disadvantages summarized below :

Advantages:

- ✓ Fertilization of fields
- ✓ Income-generating activities
- ✓ Regular emptying of latrines permits their construction in rocky
- ✓ Or high water-table contexts where deep pits cannot be dug
- ✓ Composting process kills pathogens

Disadvantages:

- ✓ Requires consistent use and maintenance,
- ✓ Or the system fails and can cause sanitary risks
- ✓ Many communities will not accept the system
- ✓ Careful operation is essential
- ✓ Urine has to be collected separately in the batch system
- ✓ Ash or vegetable matter must be added regularly

Composting process

The composting process, facilitated by composting latrines, is an aerobic biological process that stabilizes (dries and disinfects) excreta mixed with organic elements (leaves, paper) and inorganic elements (ash, soil) to produce a humus-like product that can be used as a soil additive. This product can be used by the community, or sold, after about four to six months.

An important characteristic of composting latrines is their ability to separate urine from excreta, to enhance the composting process and produce compost that is easy and safe to collect.Urine can be stored in a jerry can and used as a nitrogen-rich fertilizer, or diluted to use as an insecticide or fungicide to treat plants (ACF, 2005).

III.6.2. SOLID WASTE MANAGEMENT

The quantity and type of solid waste generated by a community depends on their living habits, which are related to their economic status. In general, wealthier communities produce more solid waste. Domestic waste favours the development of disease vectors such as flies and rodents, and looks and smells unpleasant. It can also cause environmental hazards by blocking natural or constructed drainage systems, and increasing the risk of flooding (ACF, 2005).

In an approach known as "**integrated waste management**," an individual community employs several of these options based on what is most efficient, cost effective, safe, and environmentally beneficial for that particular community. **Source reduction** relies on the individual society to reduce the amount of material that eventually is discarded as garbage. **Recycling** reconverts raw material into new products through a complex process. During **composting**, organic waste materials decompose, forming a nutrient rich soil-additive as the end product called “compost.” **Landfilling** utilizes a minimum amount of space to dispose of waste in a safe, closely monitored area. **Combustion** or **Incineration** creates steam or electricity derived from the burning of waste (James D. Englehardt et all.., 2000 in Keep America Beautiful Inc., 1996). Refuse pits and incineration are discused below :

- ✓ **Domestic or collective refuse pits**

Domestic or collective refuse pits (barials), where waste is buried, are one of the best solutions to combat the spread of vectors. They are covered daily with earth, which limits the generation of smells and proliferation of insects, and accelerates decomposition. The refuse pit must be protected from children and animals by a fence, and from surface run-off by a surrounding drainage channel. It is better to bury biodegradable waste than to incinerate it.

In rural areas refuse can be reused and controlled more easily. It is possible to develop family strategies where each home has its own refuse pit. Refuse is deposited daily in pits dug by the families themselves, and covered by a layer of soil. The pit is backfilled with soil when full, and a new pit is dug. It is possible to produce compost for reuse if only organic matter is put in the pit (ACF, 2005). The following figure is an arrangement of a refuse pit:

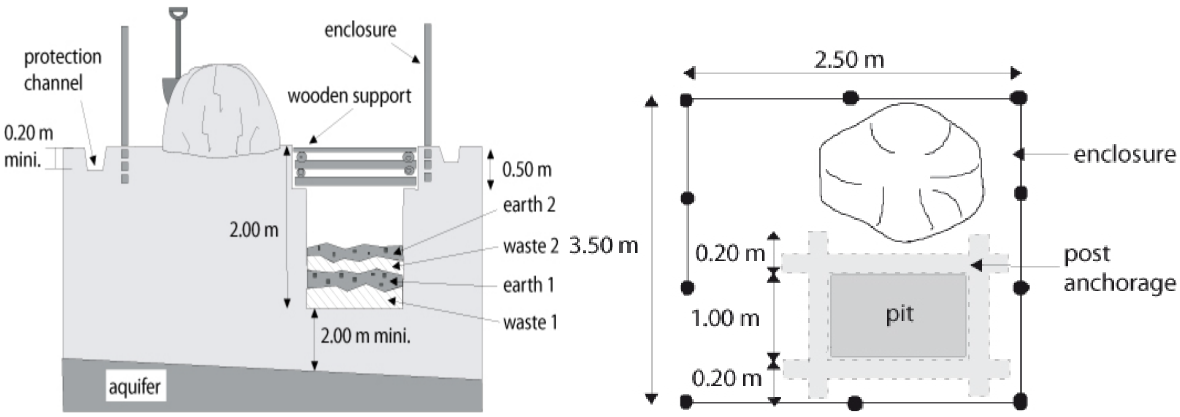


Figure 17**:** Refuse pit.

- ✓ **INCINERATION**

Incineration is advisable for the treatment of contaminated waste from hospitals or dispensaries, as well as for non-biodegradable waste. It can be done near living areas, including urban environments, although care must be taken in siting and designing the incinerator to avoid fire risks and contamination by toxic smoke. An incinerator can be easily constructed using a metal barrel it becomes more susceptible to corrosion with heat so a brick-built incinerator is recommended for more permanent use. Each type of incinerator design comprises a furnace with a hatch to remove ashes and regulate air flow, as well as a chamber for the waste with a loading trap at the top (ACF, 2005).

Key aspects for refuse collection in an urban context :

- The promotion of key social habits: collection and disposal of waste at specific locations, proactive participation of the community.
- The refuse-collection system: emptying of dustbins and containers.
- The identification of areas for final disposal: landfills.
- The transport of containers to landfills using animal-drawn carts, tractors and on-road vehicles.
- The creation of micro-enterprises that are equipped with tools and transport for refuse collection and which receive direct payment from the community.
- The separation of refuse at the final destination for treatment by burial, incineration or reuse by composting or recycling**.**
- The coordination between different actors: community, municipal water and sanitation services, health structures and other local organisations.

III.7. PUBLIC AWARENESS AND EDUCATION

Public awarenes activities must be done through water supply, sanitation and hygiene promotion to all stakeholders in WASH sector by the inclusion of beneficiaries. Sanitation and Hygiene promotion starts in the Village Level Demand Assessment phase when communities, with facilitation from trained members of the Hygiene Promotion Team, identify hygiene behavior patterns and changes by themselves. Sanitation and hygiene awareness activities are then integrated in a package of improved services at the household, community and/or at school level.

Some of the key principles relating to sanitation and hygiene promotion in WASH sector strategy are:

- ✓ **Emphasis on behavioral change leading to improved hygiene** as the major intervention supported by technically sound, feasible and affordable water and sanitation options.
- ✓ **New impetus to a program of school sanitation, water and hygiene**, benefiting both pupils as future citizens and partners, and the surrounding communities.

(Dr. Khonethip Phouangphet et Al.., 2000)

III.7.1 Tools and Methodologies for Sanitation and Hygiene Promotion

Some of the successful tools and methodologies that have been developed include the Sanitation Ladder, innovation in Sanitation and Hygiene Promotion, and School Sanitation and Hygiene Promotion.

- **The Sanitation Ladder**

The Sanitation Ladder defines a number of technology options for sanitation improvements in rural communities. This can be summarized in various technically feasible options and each one includes:

(i) A brief explanation of the main characteristics, using pictures and graphs; (ii) The advantages and disadvantages; (iii) The materials required for the construction – external and locally available materials; and (iv) An estimation of the initial investment cost, operation and maintenance cost and requirements. (Dr. Khonethip Phouangphet et Al.., 2000).

- **Innovation in Sanitation and Hygiene Promotion**

  As innovation, Sanitation and Hygiene Promotor can use the community dialogue approach to develop a ‘show- case village’. He or she can also use multimedia equipment to facilitate the community discussion and raise hygiene awareness. One of equipment used is digital cameras to capture ‘a day in the life’ images of village activities in some of the target villages. By the end of the day, the images are prepared and ready for use in discussion with the community. We can use the taken images to highlight the existing positive and negative behavior patterns. We therefore discuss possible interventions for changing these behavior, such as improvement of the water supply and/or sanitation situation.

- **School Sanitation and Hygiene Promotion**.

Actually we use a Field Kit for Hygiene Promotion at Schools that consists of a series of pictorial information sheets, and stories. The approach to be followed is similar to Participatory Hygiene and Sanitation Transformation (PHAST) and Participatory Rural Appraisal (PRA) techniques. (Dr. Khonethip Phouangphet et Al.., 2000)

III.7.2. ENVIRONMENT MANAGEMENT

Integrated Environmental Management

The design of sanitation improvement projects will ensure that the environmental consequences are adequately considered during the planning process. The risk of pollution through different sanitation approaches will be assessed in order to use the option which will minimise impacts on the environment in the most cost effective way. The Integrated Environmental Management (IEM) Guidelines have been prepared on what level of impact assessment to use for different types of projects. Where it is envisaged that a significant environmental change may result, public awareness and participation is essential.

Information must be presented in an evenhanded manner in order to convey the potential costs and trade-offs. For example, comparision of the costs of avoiding pollution with those of treating the pollution after it has happened should be accompanied by an explanation of the receiving water quality objectives.

Thus Environmental Impact Assessment (EIA) procedures should be followed during the design and siting of waste water treatment works and waste disposal sites. As the degree of complexity may vary according to the anticipated risk, appropriate risk assessment procedures need to be developed. The tree planting done espacially near the water course should be encouraged for the protection of environment against negative impacts due to climate change.

IV. DISCUSSION OF WATER AND SANITATION ACCESS ISSUES

IV.1.IMPACT OF WATER SUPPLY IN SAHEL

In many villages of Sahel region, there two types of water supplies mainly used by the population that are **hand dug wells** and **borehole pumps**. Hand dug wells may be traditional and modern. Traditional hand dug wells are unlined and unprotected holes, many less than 15 meters deep and are manually built with for example: hoes, picks and shovels into the water table. These wells are very common in rural areas, but they are subjected to pollution/ contamination by various means, sometimes the produced water is of unacceptable quality, and this can be the cause of potential health risks to users (Andrea C. Telmo 2002 in Morgan 1990). Runoff water can bring many types of contamination from the surrounding area and then drains into the well during the rainy season period. Also stagnated surfacewater contaminated by the feet of users or animals can seep through the ground and enter the well, and again this contamination can be brought into the well by the water collection vessels, such as buckets and ropes, that usually lie around the unhygienic opening of the well. Spilt water generated while collecting water can splash against the feet of users, picking up contamination, and fall back into the well (Andrea C. Telmo 2002 in Cairncross and Feachem 1993). These uncovered and not protected wells are also unsafe because children, animals, and foreign objects can fall into them. In addition to this, they can structurally fail because the interior is unlined; during construction the well can collapse on well diggers working inside the well or after completion the well can collapse under the users collecting water (Andrea C. Telmo 2002 in Watt and Wood 2001).

In the village, traditional hand dug wells may be classified as improved or not improved (Here, the term “improved” also refers to technology type, but it does not have the same meaning as WHO/UNICEF’s definition of improved water supply technologies). Not improved traditional wells are lined at the mouth with pieces of wood, as shown in Figure 18. This wood gives a more stable surface to stand on while the water collection. It also raises the opening/ mouth of the well a small amount above the surrounding ground surface so that runoff and spilt water are diverted from the opening of the well. This helps to prevent runoff and spilt water from entering and contaminating the well and or eroding the top of the well.

Improved traditional wells are raised further above the ground surface by a wellhead. Wellhead of the improved traditional well is higher above the ground surface than the wood wellhead of the not improved traditional well, it provides more protection from contamination by runoff and spilt water and the eroding action caused by this water. The mortar and rock are also more structurally sound and permanent than wood. Since this type of wellhead is higher from the ground surface, it is more visible so the chances of people or animals falling into the well are reduced, and it is less likely that foreign objects will fall into the well. Modern hand dug wells in the villages are lined with concrete rings and contruction is expensive. (Andrea C. Telmo, 2002).

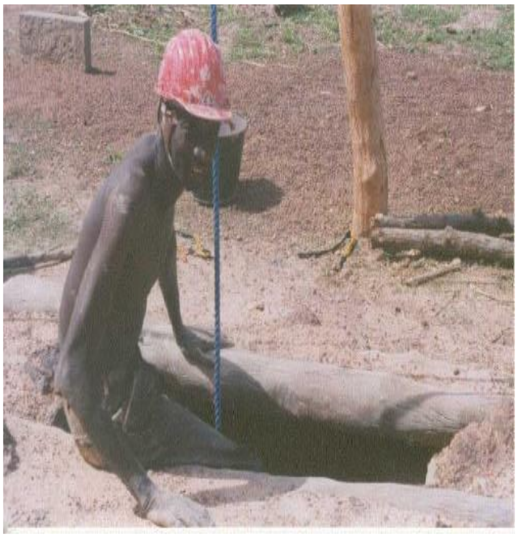


Figure 18**:** Not Improved Traditional (left) and Improved Traditional (right) Wells with a wellhead first with wood and secondly with concrete (source: Andrea C. Telmo, 2002).

IV.2 TECHNIQUES TO IMPROVE RURAL WATER SUPPLY

A hand dug well has three main parts: intake, shaft, and wellhead (See Figure 19). The intake is the bottom section of the well that taps into the aquifer, supports the exposed section of the aquifer, and permits water to flow in while preventing solids from entering into the well. In stable geological formations (e.g. in sandstone or fissured rock) it is possible to eliminate this component, but in conditions where the aquifer is made of sand or gravel it is necessary for the functioning of the well (Andrea C. Telmo 2002 in Watt and Wood 2001).

The shaft is the middle part of the well. The lining of the shaft serves to retain the well walls in place, prevents inflow of potentially contaminated water near the surface, and provides a foundation for the wellhead. Even if a well is sunk into self-supporting rock, the top few meters should be lined and made watertight to avoid the risk of collapse at the top of the well. The intake is sometimes built telescoped and “floating” inside the shaft lining in order to prevent cracking or collapse of the shaft lining if the intake settles.

The wellhead is the top section of the well which seals the well and prevents foreign objects from entering the well (Andrea C. Telmo 2002 in Watt and Wood 2001).

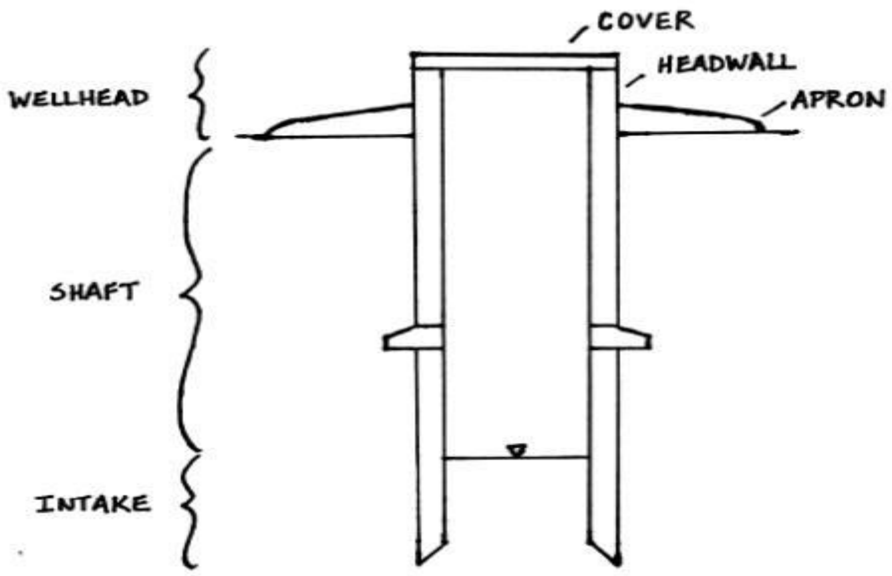


Figure 19**:** Diagram of Hand Dug Well (source: Andrea C. Telmo 2002)

There are many ways to improve the *safety*, *permanence*, and *water quality* of traditional hand dug wells. The simplest, but most important improvement to an existing well is the *construction* of a *wellhead* consisting of a *headwall* and a *drainage apron*, as depicted in

Figure 20. This single measure can eradicate guinea worm (Andrea C. Telmo 2002 in Watt and Wood 2001) and significantly reduce other health risks, such as the transmission of hookworm (Andrea C. Telmo 2002 in Pickford 1998). Raising the wellhead above the surrounding ground surface by the construction of a headwall prevents runoff water and spilt water from entering the well and reduces the chances of people or animals falling into the well. The addition of a drainage apron diverts water away from the wellhead area, preventing water from pooling at the surface near the well opening, and provides a structurally sound and more hygienic surface for well users to walk on and rest their water collection vessels (Andrea C. Telmo 2002 in Watt and Wood 2001).

Users should also be instructed and adviced not to stand on the headwall while drawing water in order to reduce the chance of contaminated spilt water from entering the well (Andrea C. Telmo 2002 in Cairncross and Feachem 1993).

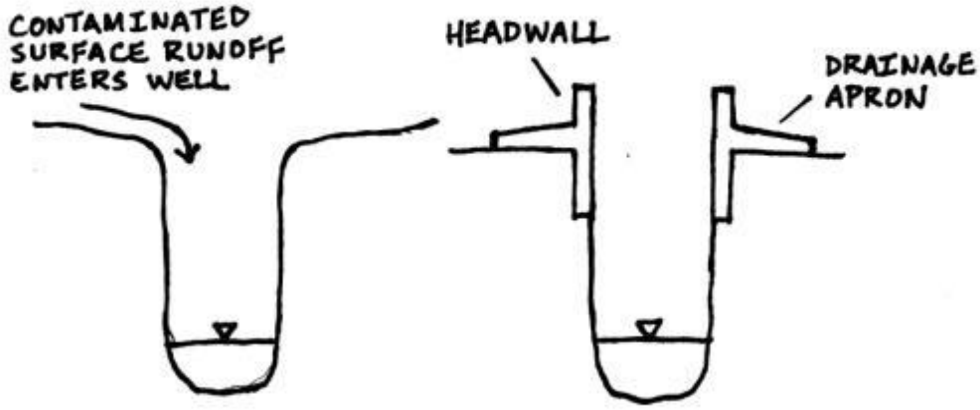


Figure 20**:** Improvement of Hand Dug Well **(**source: Andrea C. Telmo 2002 in Watt and Wood 2001)

Placing a cover slab made of wood or concrete on the well reduces the risk of foreign objects falling into the well, and the addition of a lid further reduces the risk. Lining the well with concrete, bricks, or stones prevents well collapse. A watertight lining at the top of the well eliminates the risk of contaminated seepage water from the surface from entering the well (Andrea C. Telmo 2002 in Morgan 1990).

Contamination from the water collection vessels can be reduced by placing them on a raised concrete or brick collar sur rounding the well or hanging them when they are not in use. This prevents the vessels from picking up contamination from an unhygienic wellhead and polluting the well when collecting water. Hanging the water collection vessels allows them to dry and get heated by the sun which dramatically reduces the number of bacteria on them (Andrea C. Telmo 2002 in Morgan 1990).

Even if many wells in rural areas have been built with some protective features, very few are built with all these features combined and thus yield water of questionable quality. Imploved hand dug wells can be constructed using traditional and local skills and materials, cement being the main imported and most expensive material. *Sealing the well and installing a pump is the best and most expensive way to prevent contamination and ensure a clean water supply*, but upgraded hand dug wells used properly can yield water of good quality without the need of a handpump (Andrea C. Telmo 2002 in Morgan 1990). Figure 21 shows a hand pump in the village of rural areas. If the pump is installed far from households, at an inconvenient location the villagers have deemed it useless to pay for its repair.

Figure 21: Borehole Pump

IV.3. IMPACT OF SANITATION ACCESS IN SAHEL (RURAL AREA)

Most of sanitation facilities in the villages are traditional pit latrines. The common pit latrine is usually a hole dug in the ground, with a cover slab made of wood, mud (or occasionally mortar) overlaying the wood, and some types of upper structure built for privacy. This latrine can function well if the pit is deep, the inside of the structure is dark, the slab floor is a smooth and impervious surface that is kept clean, and a cover plate is used to prevent flies from entering the pit. However, in most cases the pit is shallow, the structure allows a lot of light in, the slab is not clean and is simply muddy and wooden floor, and a cover plate is not used. Most pit latrines are open pits that smell bad and are a breeding area for flies that can carry disease (Andrea C. Telmo 2002 in Morgan 1990). In Africa the most common type of “unimproved” latrine has a slab made of wood that is covered with mud to make a floor, as shown in Figures 22 and 23 (Andrea C. Telmo 2002 in Pickford 1995).

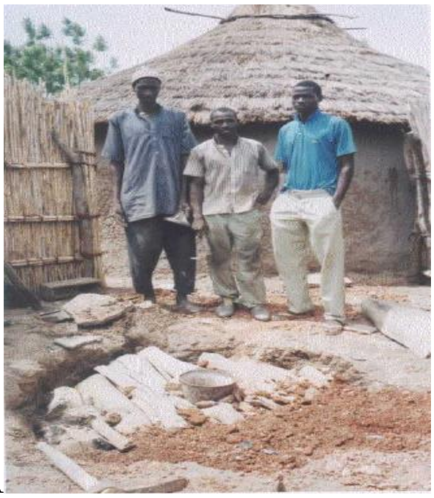
A  **B** 

Figure 22**:** (A) Wood Slab of Traditional Latrine Floor

Figure 23: (B) Traditional Latrine

A pit latrine that is too shallow or too foul, with the contents too close to the user, smells bad and there is a greater chance of the spread of disease. The wood and mud floor of a traditional latrine is difficult to keep clean, and a floor that is not clean and does not allow water to drain away is unsanitary and provides a breeding ground for mosquitoes and hookworm larvae. The floor of a traditional latrine is also subject to deterioration from weathering. Pit latrines without supported sides can collapse from the inflow of surface water that erodes the sides, and the wood slab is subject to attack from termites or rot which can cause collapse (Andrea C. Telmo 2002 in Pickford 1998).

IV.4. TECHNIQUES TO IMPROVE RURAL SANITATION

There are many ways to improve traditional latrines. Simple pit latrines can be improved by plastering the mud floor with mortar, making the floor surface smooth, impervious, and sloping (Andrea C. Telmo 2002 in Pickford 1995). This makes the floor easier to clean and allows for water to drain away. The simplest and cheapest improvement of pit latrine is to install a prefabricated reinforced concrete slab (see figure 24). This makes the latrine more structurally sound and easier to clean. A mortar or concrete floor can also prevent hookworm transmission. Another possible improvement is the use of footrests which make it easier for users to position themselves over the hole and prevents them from fouling the slab. Covering the hole with a tight- fitting lid aids in the control of flies.

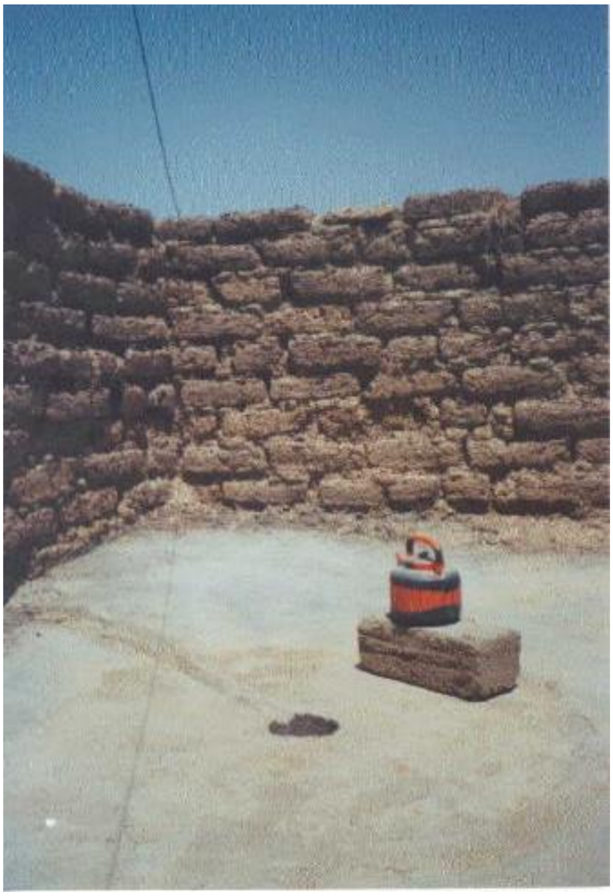


Figure 24**:** Improvement of a simple pit latrine by slab in Reinforced Concrete

The need for concrete reinforcement, as used in a flat slab, can be reduced or even avoided by making the slab slightly domed or conical in shape (See Figure 25). A traditional latrine with a strong floor made of wood and mud can be improved by placing a small slab, or "finishing/ prefablicated slab," over the center. Since this slab is not a structural bridge over the pit it does not need reinforcement (Andrea C. Telmo 2002 in Cairncross and Feachem 1993).

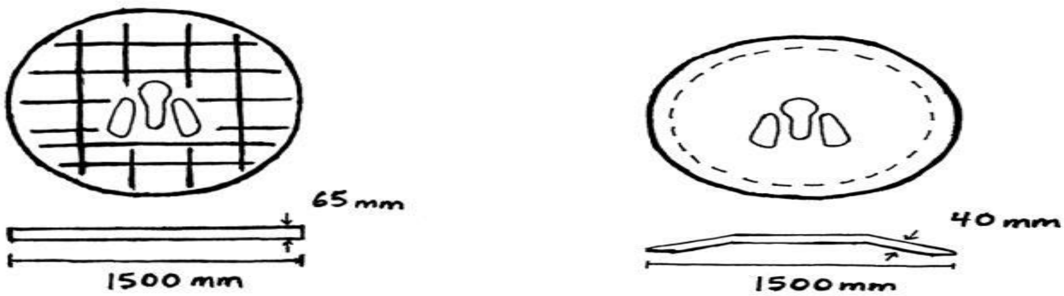


Figure 25**:** Plan Views and Cross-sections of Reinforced (top) and Unreinforced (bottom) Concrete Slabs (source: Andrea C. Telmo, 2002 in Pickford 1998)

Ventilated improved pit (VIP) latrines (See Figure 13) reduce the two main disadvantages of conventional pit latrines, the smell and the flies (or mosquitoes). Due to the action of wind passing over the vent pipe, inside air rises and escapes to the outside, creating a downdraft of air through the hole in the slab (Andrea C. Telmo 2002 in Cairncross and Feachem 1993).
If the latrine in situated where there is no wind, the pipe can be placed on the sunny side of the latrine and painted black (if the pipe is not made of a dark material) so that the air inside the pipe is heated by the sun and rises. This circulation of air removes odors emanating from the pit (Andrea C. Telmo 2002 in Pickford 1995).
The screened vent pipe prevents flies that are attracted to the odors from flying into the pipe and entering the pit. Some flies may enter through the hole in the slab, but the screened vent pipe prevents flies that are trapped in the pit from escaping as they fly towards the light at the top of the vent pipe and they will eventually die in the pit (Andrea C. Telmo 2002 in Cairncross and Feachem 1993).

IV.5 USAGE AND SOURCES OF WATER IN SAHEL REGION

People in Sahel are actually using water in different activities ranging from domestic uses (drinking, cooking, ablutions, bathing, clothes washing, and dish washing), crop irrigation, animals needs, at hospitals and schools, in industries, fisheries,... Water that is suitable for drinking is also used for cooking and religious ablutions. Sources of water may be found from rainwater (by water harvesting), surface water and groundwater (dug wells and drilled boreholes by manual water drawn or the use of pumps).

V. PROBLEM-SOLUTION ANALYSIS

This chapter consists of problem-solution analysis based on the results from the previous chapter and the actual information of Sahel regional areas about of water and sanitation access problems. It has three sections from which we find problems and technical solutions relating to water supply, excreta disposal and waste (wastewater and solid) disposal. The information is arranged in tables 7 ; 8 and 9 , each one contains problems mainly found in Sahel region, risks or negative impacts caused by such problems and the proposed technical solutions to those problems.

V.1. WATER SUPPLY RELATED PROBLEMS-SOLUTIONS

Table 7**:** Problems, Risks and Solutions for water supply

Problems	**Risks**	**Solutions**
Lack and insufficient drinking water	Contamination of WASH related diseases, high price of drinking water, use of unsafe source of water, conflict of water sharing between the family members, increase of poverty,….	Finding means (money and new technology) to increase the production of drinking water. The construction and rehabilitation of many sources of water, water treatment (both at the source and at home) and public awareness (inclusion of all water actors).
Lack and Bad water exploitation	High price of water, use many resources with low production, increase of poverty…	Availability of both human and material resources for water exploitation
Contaminated water source (see in Appendix 9)	increase of WASH related diseases, increase of poverty,	Construction and use of water treatment plant near the water source before the distribution, household water treatment, sanitation and hygiene promotion
Stagnant water (see in Appendix 9)	Development of microorganisms and vectors that can cause diseases, contamination of nearby unprotected water sources, environment disruption…	Eradication of every stagnated water by creating water drainage channels
Insufficient water sources	Contamination of WASH related diseases, high price of water, spending much time for water	Finding more means (money and new technology) to increase the production

	collection, conflict of water sharing between the family members, increase of poverty,	of water. The combination of many sources of water (rainwater harvesting, groundwater exploitation and surface water treatment) should be encouraged.
Low water production and high water demand	Increase of water prices, lack water for basic needs (domestic, irrigation, schools and hospitals…), poverty increase, and water related diseases.	Finding more means (money and new technology) to increase the production of water. The combination of many sources of water (rainwater harvesting, groundwater exploitation and surface water treatment) should be encouraged.
Collection of water points far from households	Sex violence, spending much time of water collection, increase of poverty…	Water collection points should be near and not far from households at least 500m in urban areas and 1000m in rural areas
Unprotected water sources (see in Appendix 9)	Both pollution and destruction are likely to happen due to runoff water, animals and human sharing the same water source….	Protection of water sources against animals and water runoff by respectively fencing, raising the wellhead (curb), providing washing place and animals drinking facility
Insufficient water storages containers (size and number) at home	Insufficient water stored at home, conflict of water sharing between the family members,	Choose and find enough water storage containers for every family (water tanks for rainwater harvesting, buckets, jerry cans…) depending on the number of family members
Unsafe water storages containers	Contamination of both water source and household water	Cleaning and wash properly water storages containers. This may be done by the use of hot water, soap and or chlorine. Household water treatment should be encouraged
Uneven distribution of water sources	Uneconomical water distribution networks (pipes, waters tanks, water points…)	Proper planning and consultation in the distribution (equity) of water sources

Poor construction of water supply systems (well, borehole, water point, storage tanks…)	Both pollution and destruction are likely to happen due to mainly runoff water, on ground soil condition, animals and human sharing the same water source….	Experts in construction of water supply systems should intervene during the design and implementation.
Poor or lack of maintenance practice of water supply systems	Both pollution and destruction of water supply systems are likely to happen then the intended purpose is disrupted (low water production, questionable water quality)	Regular maintenance practice of water supply systems should be encouraged. Training of local technicians on maintenance practice is also an utmost
Inadequate political commitment on water supply	People are likely to use unimproved water supply,	Actions oriented initiatives in water supply, investment in water supply,

V.2. EXCRETA DISPOSAL RELATED PROBLEMS-SOLUTIONS

Table 8**:** Problems, Risks and Solutions for Excreta Disposal

problems	**Risks**	**solutions**
Open defecation especially in rainy season	contamination of environment, water supply, food,….and insecurity due to snake or other animals attacks, non-comfort	Sanitation and hygiene promotion, It is betted to VIP latrines. Open defecation should be avoided in any development project phase.
Bad beliefs and practices of excreta handling	Discrimination based on sex, age, handicaps, and increase of WASH related diseases	Construction of toilets for both men and women, special facilities for aged and disabled people and it is necessary to do hygiene promotion
Bad construction of toilets (see in Appendix 8)	Destruction (not durable), groundwater pollution, bad smell, attraction of disease vectors (flies), risk of users to fall into the pit, users may be contaminated etc…	Experts in construction of toilets facilities should intervene during the design and implementation.
Improper use of	Contamination and increase of	Proper use of toilet facilities should be

toilet facilities	WASH related diseases, short time of serviceability	encouraged through hygiene promotion
Unprotected toilet facilities (see in Appendix 8)	Destruction, attraction disease vectors (flies), food and drinks may be polluted, animal can enter inside the toilet, short time of serviceability (not durable),	Protection of toilet facilities can be done by providing strong superstructure with a door, fencing may bring additional security. Sanitation and hygiene promotion is of great importance
Surface and ground water contamination threat (see in Appendix 9 G&F)	Water supply pollution and contamination of WASH related diseases	Toilets (unlined pit latrines) should be in downstream and far from water sources
Bad use and insufficient hand washing materials	Contamination of WASH related diseases	Good water, soap, ash, should be available after defecation, before eating or food preparation and it is necessary to do hygiene promotion
Bad use and insufficient anal cleansing materials	Contamination WASH related diseases	Depending on the type of toilet, anal cleansing materials (water, leaves, hygienic paper,…) should be available and it is necessary to do hygiene promotion
Insufficiency or lack of local construction materials (see in Appendix 8)	High expenditure through buying and transportation of construction materials, lack or insufficiency of local laborers familiar with new materials	Investigation of the construction sites and try the possibility of using local construction technology.
Insufficiency or lack of skills in construction of toilets (see in Appendix 8)	High expenditure through hiring non local technicians	Training of local laborers (workmanship) about new construction technology of toilets facilities (improved simple pit latrine and VIP latrine).
Flooding of	Water supply and environment	construction of rainwater drainage

excreta disposals	pollution, attraction of disease vectors (flies), contamination of WASH related diseases, bad smell,	systems (channels, ditches,…), proper positioning of excreta disposals (normally they should be built in the place not prone to flooding)
Poor hygiene of toilets	Attraction of disease vectors (flies), contamination of WASH related diseases, bad smell,	Regular hygiene practice of toilets, hand washing, covering of water, food and drinks, hygiene promotion….
Poor or lack of maintenance practice of toilets facilities	Destruction of toilet its self, development of contaminating microorganisms, degradation of the use, contamination of WASH related diseases, bad smell,	Regular maintenance practice of toilets, the correct use of facility as intended, education on hygiene promotion may add a big value.
Lack and insufficient sanitation access	Spread of fecal human matter, bad smell, contamination of WASH related diseases,	Construction of additional sanitation facilities (improved toilets, bathing and washing areas, menstrual facilities for ladies…)
Lack of (body and clothes) hygiene (see in Appendix 9)	contamination of WASH related diseases (skin disease), bad smell, hygienic discrimination,	Construction of sanitation facilities like bathing and washing areas, menstrual facilities for ladies, education on hygiene promotion
Insufficient excreta disposal	People are likely to use open defecation which is bad practice, environment pollution, Spread of fecal matter, contamination of WASH related diseases,	Increase the number of toilets (family, public…)
Not covered food and drinks	Attraction of disease vectors (flies) that can pollute food and drinks, contamination of WASH related diseases,	Proper handling food and drinks, proper cooking and avoiding of cold consumption, wash and peel well the fruits before eating, hygiene promotion
Ignorance or lack of valuation of	Environment pollution, poverty,	Composting, production of energy (biogas),

excreta waste matter		

V.3. DRAINAGE, SOLID WASTE AND WASTEWATER DISPOSALS RELATED PROBLEMS-SOLUTIONS

Table 9**:** Problems, Risks and Solutions for Drainage, solid waste and wastewater disposals

problems	**Risks**	**Solutions**
Poor and lack of waste management skills (see in Appendix 10)	Environment pollution, increase of poverty, Attraction of disease vectors (flies) that can pollute food and drinks, contamination of WASH related diseases...	Education and practice of waste management methods: waste collection facilities (bins, sewerage systems), reuse, recycling, damping sites or landfilling, incineration, stabilization wastewater pond…
Lack or insufficiency of waste disposals (see in Appendix 10)	People are likely to spread waste everywhere which is a bad practice, environment pollution, contamination of WASH related diseases,	Construction of more waste disposals facilities, introduce rules governing waste disposals…
Irresponsibility of waste management (see in Appendix 10)	Increase of waste spread everywhere, environment pollution, contamination of WASH related diseases,	Creation of local waste management organization
Presence of stagnant water pond (see in Appendix 9& 10)	Vector breeding sites, contamination of nearby water supply, environment pollution, contamination of WASH related diseases	Construction of drainage systems (channels, ditches…), eradication of all water stagnating after the rain through drainage and soak pits…

Poor and lack of hazardous waste management	Source of cancers, environment pollution,	Non-biodegradable, medical, industrial, radioactive…wastes should be separated and disposed correctly with great attention.
Flooding of waste disposals	Water supply and environment pollution, attraction of disease vectors (flies), contamination of WASH related diseases, bad smell,	construction of rainwater drainage systems (channels, ditches,…), proper positioning of waste disposals (normally they should be built in the places not prone to flooding
Improper position of waste disposals (see in Appendix 10)	waste disposals are prone to be flooded or washed out by wind, they are subject to destruction,	Investigation of the construction sites, proper positioning of waste disposals (normally they should be built in the places not prone to flooding
Non appreciation of waste (solid or liquid) value	Environment pollution, poverty, health related problems	Encouragement of composting, recycling, reusing, energy production,…should be, investment in waste

NB : For more information about WASH related diseases see in appendix 7

VI. CONCLUSION AND RECOMMENDATIONS

V.1.CONCLUSION

Better access to water and sanitation facilities or services for people in the whole world is now of a paramount deal for all water and sanitation projects. This project study was conducted at International Institute for Water and Environmental Engineering (2IE) and had aim to introduce technical solutions for better access to water and sanitation in dry Sahel Areas.

The objective of the work was successfully met as we have now a compiled document of overview to WASH sector basics, a summary of water and sanitation problems in Sahel and finally analysis of WASH problem-solution method to in improving water and sanitation access in the same areas.

During our research project, the main problems in Sahel region have seen to be based on insufficient knowledge, unimproved facitlities, poverty and inadequate policy on water and sanitation. The solutions to these problems are to use new technology by rehabilitating and constructing more WASH facilities, investment in water and sanitation projects and actions oriented initiatives from both governments and its stakeholders. Most of the problems found can be solved through comprehensive management of water and sanitation resources and its demand. The provision of both water and adequate sanitation was found to be by bringing new infrastructure, maintaining the existing ones and behavioural change of the population in water management, disposing of human excreta[5], waste water and household refuse.

We conclude that the use and development of this document will contribute much on better access to safe water and basic sanitation services with improved hygiene practices that will directly reduce morbidity and mortality, improve health and education outcomes, and contribute much to the reduction of poverty and sustainable development.

V.2. RECOMMENDATIONS

During this research work we encountered and identified some obstacles that may cause slow or negative progression of any water and sanitation project. To improve it, the following is a part of recommendations for different stakeholders in WASH field:

- To the local governments of Sahel region : it is of great importance to strong institutions or departments in charge of water supply, sanitation and hygiene. These departments should fulfil their tasks of for example waste management referring to the regulations of WHO and or local ones.

- To the donors and humanitarian organisations of WASH related projects : before starting any project, they should ensure that all the population is aware of it. The consultation, training and education of beneficiaries should be done prior the implementation of projects as it will contribute much on the protection, maintenance, and better use of WASH facilities.
- To the people of sahel : water is life, it is better to sustain our life through good water management, regular practice of sanitation and hygiene (hand washing, cleanliness,…) and environment protection (Tree planting).
- To the academic institutions, researchers and implementors of WASH projects : the creation of a platform for all WASH actors should be encouraged as the information sharing will be easy. The innovations of problem solution in WASH sector must be shared, analysed and then improved before any general implementation.
- Any WASH research project should be given both sufficient financial means and time. The collection of data from the main source (terrain) should be much encouraged.
- Further reseach on the similar topics in Sahel should be conducted and the field visiting should be done to collect the information about the actual situation on the ground.
- This report can be saved as a document for continuing students and or other researchers in WASH sector.

LIMITATIONS

During this research project, we encountered problems which were mainly based on the time allocated for the whole work, updated material sources and availability of supervisor. In the following we have some of encountered limitations :

- We have been given a time less than one month to conduct this research work and compile the report. We wish it should be better if the time is more than three moths to do the same research project.
- Normally we wished to use the updated data sources so to express the actuall situation of the case study but few of reference books and papers were obtained and used in our report. We have recalled from old sources to be able to conduct this work.
- As the supervisor had other tasks to fulfill, we did not very much collaborated each other and it was for us to rely much on us rather than on supervision.
- French language communication was a barrier as this report was conducted in the institution where this language is the most spoken one.
- During our work production, we discussed a lot on rural areas rather than in the urban sides. This was due to many material sources done for rural areas and the towns or urban areas were not much discussed.

REFERENCES

BIBLIOGRAPHY :

- **Action Conte la Faim (ACF) 2005**, Water, sanitation and hygiene for populations at risk.
- **Andrea C. Telmo 2002**, Supply And Sanitation Study Of The Village Of Gouansolo In Mali, West Africa
- **Awuah, E., Nyarko, K.B., Owusu, P.A., & Osei-Bonsu, K. 2009**. Small town water quality, *Desalination*, *248*, 453-459.
- **Dr. Khonethip Phouangphet et Al.., 2000**, Sanitation and hygiene promotion in Lao PDR
- **James D. Englehardt et al.., 2000**, Solid Waste Management Health and Safety Risks: Epidemiology and Assessment to Support Risk Reduction.
- **Médecins Sans Frontières (MSF) 2010**, Public Health Engineering in Precarious Situations, Second Edition
- **Natasha and Al… 2014**, Resilience in the Sahel, Building better lives with children
- **The sphere project 2011 edition**, Humanitarian Charter and Minimum Standards in Humanitarian Response.
- **United Nations (UN) report 2015**, Progress on Sanitation and Drinking Water
- **United Nation Children's Fund** (**UNICEF)** water, sanitation and hygiene strategies for 2006-2015A WATER
- **World Health Organisation (WHO) 1992** A Guide to the Development of on-Site Sanitation.
- **United Nation Children's Fund** (**UNICEF) Annual Report 2010**, Water, Sanitation and Hygiene

WEBGRAPHY:

1. http://www.un.org
2. http://hdr.undp.org
3. http://www.watercache.com
4. www.sphereproject.org

APPENDICES

LIST OF APPENDICES

Appendix 1: Some issues to think about when installing a rainwater harvesting system

1. **Flying Pipes**

This issue is not necessarily bad as it allows for a higher efficiency of collection, but for most people, they don't want to see PVC pipe flying overhead at their homes. Some other things to think about is the possibility of damage to the collection pipes from storms and injuries to people who could run into the pipes.

2. **Transparent Water Tank** (with material that allows sunlight inside)

Do not use a translucent plastic tank for rainwater storage! The system may look great right after being installed, but unless you constantly put chlorine bleach into your tank, then the water inside the tank will grow algae and will look like pea soup. These translucent tanks are meant for chemical storage not for raw water storage

3. **Water level indicator using a clear pipe**

Well, as in the previous issue with the clear or translucent tank material, the same phenomenon will occur with these clear pipe or clear flexible tubing water level indicators. The water in the indicator pipe is exposed to sunlight which promotes the growth of algae inside the clear pipe. Even if the indicator has a drain valve in it, the water vapor trapped in the clear pipe can still grow algae.

4. **First-flush diverter that mixes with good rainwater**

The purpose of a first-flush diverter (see image 4 below) is to divert the first bit of rainwater that drains from your collection surface. This first bit of rainwater has the highest concentration of dust and other particles. The diverter shown in this image is normally called a "poor man's diverter". As you can see though, the initial flush of water that has filled the pea-trap shaped pipes just pushes into the collection tank. In this configuration, you get no benefit... you might as well connect the downspout pipe straight to the tank inlet.

Image 1: flying water pipe

Image 2: clear or transparent water tank

Image 3: first flush water diverter

Image 4: clear or transparent water level indicator pipe

Source: http://www.watercache.com, innovative water solution

Appendix 2 **:** Usual warking range of hand water pumps

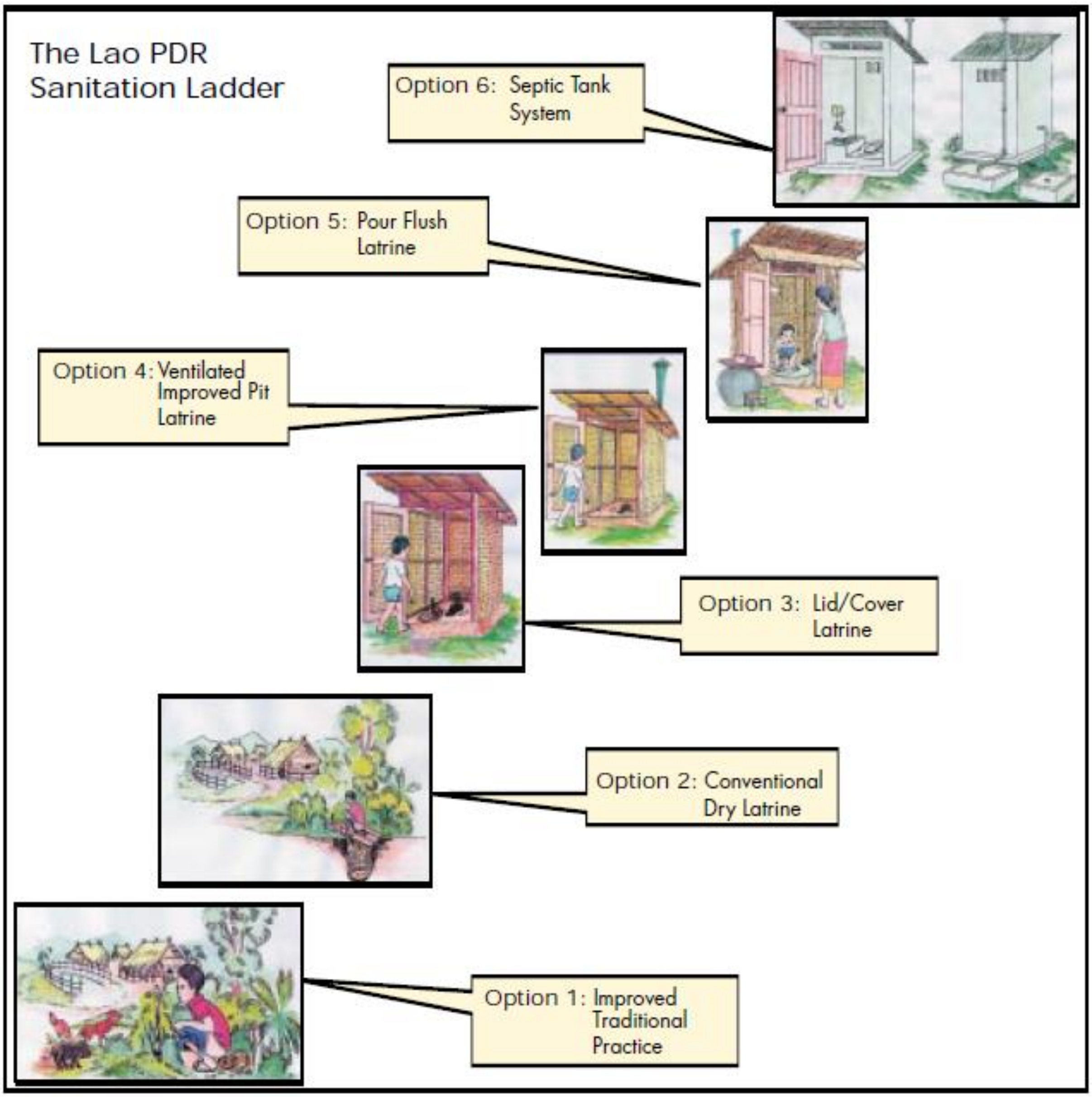
Table 9.XVI: Usual working range of handpumps.

	10 m	20 m	30 m	40 m	50 m	60 m	70 m	80 m	90 m	100 m
....	Tara	....								
....	Vergnet HPV 30	....								
	....	....	India Mark 2	....						
	....	....	Aqua/Afridev	....						
	....	....	Kardia	....						
	....	....	Vergnet HPV 60	....						
	....	....	....	Volonta	....	....	....			
	....	....	....	....	Monolift	....	....	....	....	
				....	....	Vergnet HPV 100 (*)	Vergnet HPV 100 (*)	....	....	....

* 2 persons pumping.

Source : ACF 2005

Appendix 3: Sanitation and hygiene promotion by Sanitation Ladder Method



Source: Dr. Khonethip Phouangphet et Al.., 2000

Appendix 4: Pathogens present in urine, excreta and grey water

Table 13.II: Pathogens present in urine, excreta and grey-water (domestic wastewater) (source: Franceys, Pickford & Reed, 1992).

Pathogen	Name of the disease	Present in urine	Present in excreta	Present in grey-water
Bacteria				
Escherichia coli	Diarrhoea	X	X	X
Leptospira interrogans	Leptospirosis	X		
Salmonella typhi	Typhus	X	X	X
Shigella spp.	Shigellosis		X	
Vibrio cholerae	Cholera		X	
Viruses				
Poliovirus	Poliomyelitis		X	X
Rotaviruses	Enteritis		X	
Protozoa - amoeba or cysts				
Entamoeba histolytica	Amoebiasis		X	X
Giardia intestinalis	Giardiasis		X	X
Helminths - parasite eggs				
Ascaris lumbricoides	Roundworm		X	X
Fasciola hepatica	Liver fluke		X	X
Ancylostoma duodenale	Hookworm		X	X
Necator americanus	Hookworm		X	X
Schistosoma spp	Shistosomiasis	X	X	X
Taenia spp	Tapeworm		X	X
Trichuris trichiura	Whipworm		X	X

Source: ACF 2005

Appendix 5: List of the major vectors and the diseases that they transmit, the environments that favour their development, and the important measures that can be taken for their control.

Vectors that can pose health risks.

Vector	Health risk	Favoured environment	Control measures
Flies	Eye infections (particularly among children), diarrhoeal diseases	Exposed food, excreta, dead animals	Improve environmental sanitation (collection and disposal of organic refuse, dead animals etc.) and use of VIP-type or pour-flush latrines Promote the use of screens on windows (houses, hospitals etc.) Spray refuse with insecticides
Mosquitoes	Malaria, filariasis, encephalitis	Stagnant water, mainly in the perimeter of flooded areas, and slowly flowing water bodies	Removal of stagnant water sites (puddles, cans, tyres etc.) or spraying with larvicide
	Yellow fever and dengue	Stored water in or near homes Pond or rain water accumulated in containers, cans or old tyres	Insecticide control by spraying mosquito-infested sites Promote the use of mosquito nets
Mites	Scabies, scrub typhus	Crowded areas and poor personal hygiene	
Lice	Epidemic typhus, relapsing fever		Improve personal hygiene In severe cases, spray people and clothes with insecticides suitable for use on humans
Fleas	Plague, murine typhus	Infected animals, particularly rats (see 'Rats' below)	Fumigate rodent burrows with insecticides Treatment of beds In severe cases, spray people and clothes with insecticides suitable for use on humans
Ticks	Relapsing fever, chickenpox	Infected animals (see 'Rats' below)	Chemical control in on the perimeter of the community Clear the vegetation to 50-100 m around the home or community In severe cases, use chemical control in houses (with caution)
Rats	Rat-bite fever, lepthospirosis, salmonella	Food not correctly protected, refuse	Improve environmental sanitation Use rodenticides Use traps at refuse or food-storage sites

Source: ACF 2005

Appendix 6: Advantages and desadvantages of simple,VIP and poue flush latrines

Table 13.VII: Advantages and disadvantages of simple, VIP and pour-flush latrines.

Advantages/Disadvantages	Simple latrine	VIP latrine	Pour-flush latrine
Construction			
Simple technology	+++	++	+
Low cost (use of local materials possible)	+++	++	+
Construction time	+++	++	–
Potential for improvement	–	Possible upgrade to pour-flush latrine	Possible connection to a sewerage system
Use & maintenance			
No necessity for water	+++	+++	–
Easy to use	+++	+++	–
(efficiency of the system independent of its correct utilisation)		The interior needs to be dark	Water must be providedand used
Maintenance	++	++	+++ +*
Adaptation to type of anal cleansing	++ Adapted to water cleansing if plastic or concrete slab is installed and if soil conditions allow	++ Adapted to water cleansing if plastic or concrete slab is installed and if soil conditions allow	Possible blockages when solid materials are used
Hygiene & comfort			
Privacy	+ Latrine far from house (bad smell)	++ Latrine near the house	+++ Latrine inside the house
Absence of smell	+	++	+++
Fly control	–	++	+++
Mosquito control	–	+	+++
Hygiene	+++ If correctly designed, built, used & maintened	+++ If correctly designed, built, used & maintened	+++ If correctly designed, built, used & maintened
Pleasant to use	Pit is visible	Pit is visible	+++

* Impermeable soil.

Source: ACF 2005

Appendix 7: Water and excreta (WASH) related diseases and transmission mechanisms

WASH disease	**Example of caused disease**	**Transmission**	**Favorable environment for disease contamination**
Water-borne or water-washed	Cholera, shigellosis, diarrhea, salmonellosis, etc. Typhoid, paratyphoid, etc. Amoebic dysentery, giardiasis Hepatitis A, poliomyelitis, rotavirus, diarrhea	Fecal-oral bacterial Fecal-oral non-bacterial	Water contamination Poor sanitation Poor personal hygiene Crop contamination
Water-washed or water-scarce	Skin and eye infections Louse-borne typhus and louse-borne relapsing fever		Inadequate water Poor personal hygiene
Excreta-related helminthes	Roundworm, hookworm, whipworm etc.	Soil-transmitted helminthes	Open defecation Ground contamination
Beef and pork tapeworms	Taeniasis	Man–animal	Half-cooked meat Ground contamination
Water-based	Schistosomiasis, Guinea worm, clonorchiasis, etc.	Long stay in infected water	Water contamination
Water-related insect vector .	Malaria, dengue, sleeping sickness, filariasis, etc.	Biting by mosquitoes, flies	Bite near water Breed near water
Excreta-related insect vectors	Diarrhea, dysentery	Transmitted by flies and cockroaches	Dirty environment

Source: Sphere handbook 2011

Appendix 8**:** Some problems of toilets in Gaeri District-Burkina Faso (Photo : Oscar)

(A) Bad construction of VIP latrine

(B) Flies and mosquitoes in toilets

(C) Poor construction of latrine

(D) Toilets not covered

Appendix 9**:** Some problems of water points and surface water in Gaeri District-Burkina Faso

(Photo : Oscar)

(A)Lack of maintenance

(B) No cleanliness around the water point

(C) Unprotected well

(D) Water ponding inside water point

(E) Poor maintenance of water point

(F) Stagnated water around water point

(G) People are using unsafe water

(H) Animals are sharing the same water with people

Appendix 10: Problems of runoff and waste management in Ouagadougou (photo : Theoneste)

(A) Stagnated water in the channel

(B) Unrehabilitated channel sides

(C) Plants growing into the channel

(D) No rehabilitation of the channel in 2iE

(E) Unmanaged solid waste

(F) No protection of scavenger