



WASH TECHNOLOGY OPTIONS FOR SCHOOL FACILITIES
A HANDOUT FOR THE ARC WATERSCHOOLS PROGRAMME
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This publication is work in progress. Any comments, additions or suggestions for corrections are more than welcome.

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Colophon

This handout was created by Dick Bouman of Aqua for All, Henk Holtslag and Frederik Claasen of EMF as a contribution to ARC's WaterSchools programme. This programme intends to improve water and sanitation in religious schools. In many countries, these schools receive little funding. As well as facing the same water and sanitation issues as every school, they also possess a deep understanding of the religious/cultural significance of water and cleanliness, which brings an extra dimension to these issues.

In 2005 UNICEF set a target of ensuring that all schools have adequate child-friendly water and sanitation facilities and hygiene education programmes by 2015 as part of its WASH (water, sanitation and hygiene) programme. That target year has to be postponed, but without involving faith-based schools, it will never be attained. This handout consists of a short step-by-step approach, followed by a more elaborate background document.

Sanitation is culturally sensitive and often a taboo area. Terminology is often misleading ('restroom' or 'bath room' – or 'water-closet' or 'WC' even when there is not a drop of water). In this publication we use the word 'latrine' for all types of 'toilet' and the word 'seat' for all kinds of structures used for defecation (whether a raised seat, a French or Turkish toilet, or a drop hole).

A draft reader with cases/fact sheets is provided separately. Most of the pictures are taken from third parties.

A first content screening was made by Mrs Annemarieke Mooijman and Jan Heeger.

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PREFACE BY ARC

ARC's increasing involvement with the issue of water is a story of both the development of how the environment is understood in relation to development as well as a story of partnership. When ARC (the Alliance of Religions and Conservation) was created in 1995, emerging from the world of WWF, its focus was on the major issues facing the natural environment. These included climate change; protection of eco-systems and habitats; conservation of species and so forth.

Unlike many environmental groups at that time, we always took development seriously but within the context of justice and equality. But we were unusual in this. Many of the major conservation bodies were still trying to work out their relationship with development, which they saw as a basic threat to the natural world.

It was Islam which first alerted us to the importance of religion and water conservation as part of a grander vision of our relationship with all creation. From the 9th century AD, Islam has had strict Sharia laws protecting watersheds and water holes, not just for human use but also for their use by all creatures. In all their plans for faith-based conservation work, these teachings and models were cited as something they wished to reintroduce or reinvigorate.

However, to be honest, we felt that the issue of water was so profoundly complex and riven with competing groups and ideologies, that it was an area best left alone while we concentrated on more manageable topics such as forests or land.

Enter Allerd Stikker and EMF (the Ecological Management Foundation). For Allerd, as he has written, water is the great issue facing humanity and it was his constant insistence that we had to grasp this most complex of issues which led us to start the Water Schools project. It was his vision that we should concentrate on the untapped potential of faith schools, a potential of which we had only just begun to grasp the significance.

We discovered that over 50% of all schools worldwide were either set up, run, or contributed to, by the faiths. This gave us a potential field for significant faith action. It was Allerd and EMF's vision that led us all to see faith-based schools as places not just of learning about water protection, sanitation and health but as places of practice. We began to realise that they could make a truly significant difference and that through them we could tackle the issues of water – environmental and health.

Allerd spent many days discussing with us not just the why but also the how, and through the generosity of EMF ARC was able to start a modest programme exploring the potential. This



had its first big launch at the Salisbury Conference in 2007 when faith organisations and major international development agencies began to make tentative steps towards working together.

From this meeting and from the partnership between ARC, EMF and the Rev Al Bailey of the New Psalmist Church in Baltimore, USA, links with UNICEF have begun to develop. This has led to UNICEF beginning to work as a potential partner with faith-based schools. It is in this context that this handbook has to be understood.

Around the world, there are hundreds of thousands of faith-based schools. They are administered through a vast array of local, national, regional and international networks. It might be an Anglican Diocese in sub-Saharan Africa with responsibility for as many as 100 schools; it might be a network of mosques that run hundreds of pesantrens – Islamic boarding schools in rural Indonesia; it might be a Catholic religious order running schools in South America; or the Sikhs in the Punjab and their school network. Each faith has its central body with responsibility for the overall planning and development of the educational work of the faiths.

This handbook is designed to be a crucial tool for those bodies. It offers swift and easily accessible advice, insights and technical help when planning large-scale, water-based development programmes many of which in the past have resulted in failures. Those failures often happened because the models were unsustainable or inappropriate to the specific needs of a community.

We hope that through this handbook some of those mistakes of the past can be avoided but also, more importantly, that new plans can be developed which benefit from decades of experience drawn from the international water sector as well as ARC's own specialty in working with faith communities. Thanks to our partnership with EMF and, through them, with many of the major international water bodies, we are creating truly significant alliances. This handbook is a visible manifestation of this and we are proud to have helped it come into being.

The role of the faiths is the best-kept secret in the world, but the secret is out. It is the emerging partnership between secular bodies and faith groups that gives hope for the future of millions of children around the world.

Religious understanding of water and sanitation

Water is a theological issue. Water is a theological issue in a way that, for example, forests are not, nor even the soil. The creation stories of all the major faiths feature water as both an essential element of the start of life on earth but also as a problematic one.



In the Abrahamic traditions (Judaism, Christianity and Islam) water is both life giving and life taking. It is an instrument of divine power – Noah’s Flood was sent to punish sinful humanity – and it is also a symbol of rebellion. In the Psalms, water is depicted as unruly, a force associated with chaos needing to have its boundaries set. It is further seen as a symbol of God’s life-giving gifts; for example, when Moses strikes the rock during the Israelites’ flight from slavery in Egypt and water gushes forth to stop them dying of thirst in the desert.

In Chinese mythology the greatest hero of antiquity, Yu the Great, earns his title because for ten years without ceasing he fights the Yellow River, which had broken its banks and was destroying the land and people of China. Yet water is also the element within which the powerful and protector dragon deities live and it is across the seas and oceans that Guan Yin, goddess of compassion and greatest of all Chinese deities floats.

In Hinduism, the world is born from an ocean upon which floats the supreme deity Vishnu and the end of the world will once again bring back this primal ocean, which, in time, will give birth to all life again.

Water also features in many sacred rituals from baptism to offerings to the deities. Water is sacred because the faiths have known for millennia that without water there can be no life.

Even hygiene is sacred. The earliest examples of enforced hygiene are probably the codes written down in the 2nd millennium BC for washing your hands after touching anything that is polluting. These laws, to be found in the Laws of Mani or in the laws of the Old Testament, were designed to enshrine the ritual of hand washing as both a sacred responsibility and a necessary health protection measure. In Islam this is manifest in wudu - the ritual washing before the five daily prayer times – and thus the need to provide running water and proper drainage in the mosques. Similarly, when you enter a Shinto shrine in Japan you must wash your hands and mouth and so running water and proper drainage is a central part of the shrine complex.

It is, therefore, clear that from all faith perspectives, the role and significance of water and education should be strong. If there are some contexts where that importance has been dimmed over the centuries then this is why the faiths can benefit from secular partners such as EMF or UNICEF to remind them of what they always knew but might have forgotten.

It is equally important that the faiths are able to speak openly to the secular world about the sacred dimension of water. A few years ago ARC was asked to help the World Water Forum in understanding this. When we asked the organisers why they wanted faiths to come and celebrate the sacred dimension of water, they said: ‘We know everything about water. We can



create it, break it down, engineer it, control it and destroy it. But what we have forgotten is how to have an actual relationship with it.'

This handbook brings together two worlds: the world of the experts who can manage water and the world of the faiths who understand water and our relationship with it. They come together through the medium of faith-based schools and the dramatically growing role of these schools in addressing water issues – issues of both environmental and sanitary significance.

In the Daoist religion there is a beautiful description of why a cup works as a holder of water. As the ancient sacred book, the *Dao De Jing*, says, it is the void within the cup, which makes it useful. Faith brings an ability to leave space for understanding water while technology helps to make the cup, which can carry the void, the space and the water. I think in this ancient Chinese wisdom we can see a model for partnership and I hope this handbook will help provide the material for the faiths to construct the space to hold the significance of water and its protection.

Water playing a significant part in faith is nothing new. What is new is that this wisdom and experience have been reactivated by the major secular organisations working with water. In partnership with the faiths the potential for reaching millions, if not billions, of children through faith-based school networks is now a real possibility. It could change the way ambitious targets such as the millennium development goals or their successors could be achieved.

Martin Palmer

Secretary General of Alliance of Religions and Conservation



STEP BY STEP APPROACH

Golden rules:

- 🏠 Involve all stakeholders in preparatory processes and decision making! Be gender sensitive.
- 🏠 Look wider than the school compound alone.
- 🏠 Go for the most appropriate solution for the given socio-economic situation.
- 🏠 Go for solutions that can be maintained (technically and financially).

Preparatory stage

P1. Compose a team of stakeholders and make a plan for the preparation. Involve parents, teachers, pupils, special groups, technicians and create a good balance of representation of men and women.

P2. Determine the present WASH situation at the school and try to aim one or two steps higher

Level	Typical situation
○○○○○	No safe water, no hygienic sanitation and/or no hand washing facilities
●○○○○	Some water and sanitation (such as a protected defecation area) but insufficient and imperfect
●●○○○	Pit latrines/urinals for each 50-75 children and good hand wash facilities with water and soap (or ash); hygiene education at school; but water to be brought by children, which might be treated at school
●●●○○	Pit latrines for each 50-75 children, separated by gender, and good hand wash facilities with water and soap (or ash); hygiene education at school. Water collected from nearby safe source,
●●●●○	Basic sanitation blocks (one seat per 25-50 children, separated by gender); good hand wash facilities with water and soap (or ash); hygiene education at school; safe water in school compound (>3 l/cap for drinking and hand washing); teachers have their own units.
●●●●●	Well designed sanitation blocks (one seat per 25 girls/30 boys; separated by gender; some adapted for disabilities); hand wash facilities at all critical points; school-led total sanitation/PHAST; Safe water point near classes with > 5 l/cap for drinking and hand washing; teachers have their own units (also separated by gender). (an extra plus can be obtained with re-use of water and/or re-use of compost & urine)



P3. What is the demography of the school (nr male/female teachers, nr girls and boys separately in age categories 5-7, 8-11, 12-13, 14-18. How many pupils/teachers with (physical) disabilities (and what type)? What is the growth prognosis for the school in 10 years?

P4. How many classes are there now and what are the 10-year plans? What is the (ground) size of any hard roof structures? Are there gutters available?

P5. What is the present number of water points and sanitation seats and what is their condition?

P6. Make a sketch map of the area, indicating the school compound, the school buildings (dimensions, including future plans), trees at the compound, neighbouring buildings, access roads, water sources/facilities/pipes, latrines, defecation and solid waste areas etc.

P7. Make an institutional/context analysis, including the following questions:

- 🏠 Who is finally responsible for the property (Ministry, local government/municipality, school board, church/mosque/temple)
- 🏠 Who is to do the regular operation and maintenance and what is the education level?
- 🏠 Is there a local service provider that can do exceptional repairs and at what level?
- 🏠 Are there building standards/guidelines and laws to be respected?
- 🏠 What is the distance to different suppliers?
- 🏠 Is there a nearby support organization that can work on capacity building?
- 🏠 Does the school have experience with tender procedures?
- 🏠 Is there a chance that the school will be used as a refuge in time of emergencies (different standards and demands)?

P8. Make a preliminary funding analysis:

- 🏠 What funding is available and what are the conditions?
- 🏠 What is the available annual budget for operation and maintenance?
- 🏠 Are there possibilities to earn money from the new services?

P9. Redraft the plan (time, people, communication, funding, and need for external support)



Water technology selection

The following steps are recommended to select a water facility at a specific school.

W1. Water that is safe to drink and water for hand washing. Determine the **water quantity** per pupil per day and per year; Distinguish two options: (A) minimum option for drinking and limited other use like hand washing (2-6 litre/pupil/day) and (B) most desirable option (also water for cleaning, cooking, toilets, school gardens etc.; >10 litre/pupil/day).

W2. Make an inventory of **all the potential options** in the vicinity of the school: public water scheme, nearby public improved water point, shallow groundwater, deep groundwater, stream or pond, rainwater harvesting. If there is an old supply, include the rehabilitation of the old system as an option.

Determine for each source the possible **quantity** (does it match outcome of step 1) and the **quality** (is there a need for treatment regarding physical, chemical or biological contamination?).

W3. Select the preferred alternatives from a water source perspective. Choose a maximum of 3 In case of scarcity of water or limited funds; source separation for drinking and other purposes might be an option.

W4. Determine for each selected alternative the **full chain from source to mouth** (water source development, pump/lifting device, transport, storage, treatment, provision, drainage). The position in the chain can be different (treatment before storage or even before transport; pumping after storage etc.). *Table 7 shows a matrix of possible chain elements/needs for each source type. Include also the links to sanitation, hand washing options and other desired uses.*

W5. Determine for each part of the chain the most likely choices.

This might be a complex exercise. It should be limited to technologies that are available or can easily be introduced in the area of the school. *The water portal site at akvopedia (www.akvo.org) provides many technology choices under the headings 'water access', 'pumps and distribution', 'storage and recharge', 'treatment and tests' and 'irrigation and other uses'.*

W6: Determine investment costs and operational costs and express them in cost per litre or m³ and in cost per pupil per year. *Mind that there are several new low cost solutions which can be more effective, easier to maintain and cheaper than the options traditionally applied.* Sometimes, it may be more cost effective to invest in very robust and high quality technology when this reduces the maintenance costs.

W7. Evaluate the best source option, together with teachers, parents and local experts. The best option is a balance between the desire and the financial ability for investment, use, maintenance and replacement. Do look at the entire chain: remember that a solution that serves both a community and a school has many advantages.



W8. Define with the most relevant stakeholders for the selected chain elements the most relevant design parameters that have emerged from your discussions (related to target groups, age level etc.) and hand these specifications/list of preferences to a design engineer.

Sanitation technology selection

In designing the sanitation (including options for hand washing) facilities, the following **steps** need to be taken. The steps are mainly derived from a Decision Support Tool, developed by WASTE and AKVO.

S1: decide on the **design criteria** and the desired final destination of excreta and urine. Among the design criteria are the maximum number of users, any group divisions and, for each group, any specific aspects around access, safety, hygiene, privacy etc. It is good to start from the experience with a possible existing system or a known system from another school. Do also evaluate whether eco-sanitation or urine/excreta separation is a socially/culturally acceptable option and whether there is a desire to explore other types of re-use.

S2: for **dimensioning** determine the likely number of users (gender and age specific) and the volume of excreta and urine produced daily, annually or for each emptying cycle.

S3: Determine possible **limiting factors** with regard to soil/rock, risk of inundation and space. Pre-indicate possible **sites** for the sanitary units and possible storage and treatment facilities. Remember that sanitation blocks should be at least 20 m from a (groundwater) source and 1.5 m above groundwater table. If there are prevailing winds, one could also look for the most suitable location with respects to odours. The web-based Decision Support Tool of Waste and Akvo (www.akvo.org – sanitation portal) provides a useful short list of relevant factors to be considered.

S4: Define the **desired situation** if money was not a problem and define the **'intermediate' steps**, which might be affordable and acceptable. If money were not an issue a school with only 1 latrine for 50 boys and 50 girls could dream of a concrete sanitary block with 3 flushed toilets for girls, and 1 urinal and 1 flushed toilet for boys. A more realistic intermediate step may be just to build two more pit latrines: one extra for girls and one for boys.

S5: Carry out the **design evaluation process** for each part of the chain, namely: the 'toilet'/superstructure, the collector, possible transportation/conveyance, possible treatment and possible re-use. For this purpose the web-based Decision Support Tool of Waste and Akvo (www.akvo.org – sanitation portal) is very useful. Possible options for consideration in the design process can also be found on the Akvo website.

S6: Make a choice from the selected chain options, based on technical, economical and cultural criteria and feasibility criteria (see chapter 1).

S7: With the most relevant stakeholders define the most relevant design parameters for the selected chain elements (related to target groups, age level etc.) that emerged from the discussions. Hand these specifications/list of preferences to the design engineer.



Follow-up:

- 🏠 Finalise plans for both Construction and for Operation & Maintenance
- 🏠 Secure funding
- 🏠 Undertake tendering and contracting
- 🏠 Arrange supervision
- 🏠 Carry out monitoring



1 INTRODUCTION

This paper summarizes a number of **technology solutions** for schools on water, sanitation and hygiene facilities. Technology solutions are, however, only part of the story: hygiene awareness, ownership and maintenance are equally important **and hygiene education/practice and hand washing are 7 times more effective for health than improved water supply alone.**

Regarding water the absolute minimum of **basic quantities required** for day schools per child and staff are 1 litre for safe drinking water and 1-4 litre for hand washing.

Regarding sanitation basic requirements are

- 🏠 maximum 75 children per toilet (temporary maximum; longer term target is 25 girls per toilet, 50 boys per urinal (of 1 m) and 50 boys per toilet (if there is a separate urinal)
- 🏠 separate toilet blocks for boys, girls and school staff (facilities regarding menstruation)
- 🏠 for each block there is at least one toilet for disabled users (wider door and room, ramp, support)
- 🏠 distance between school and toilets maximum 30 meters
- 🏠 hygienic hand washing facilities with soap.

We prefer solutions that are **appropriate** to the local situation. There are many definitions of 'appropriate technologies' but we define them as technologies that are effective (performance), have proper quality, are financially affordable for the users, are available in the area, and are manageable and fit into an enabling environment. They should also be environmental friendly with special attention to be given to designs that can be used by disabled pupils and teachers.

The capacity to cover operational expenses is critical for sustainable usage and these expenses must be part of the school budget. Some solutions may even provide the opportunity to generate income themselves.

Young children are afraid to use a latrine in the dark and are afraid of all the possible insects, reptiles and small animals around. Many of them are afraid of falling into the hole. About one third are afraid about 'bad powers' in the hole and 14% are afraid to be left alone. They prefer a light and well-ventilated latrine with a decent (small) hole, a grip on the wall and a door that can be locked from inside only. They might have little muscle power to use a handpump or to open a tap. And they are often too small to reach taps and handpump handles. An example: The play pump (a merry go round) is an enjoyable invention, but might breach the children's rights if they have to pump for the community, as well.

School solutions may be different from community solutions or family solutions. Children need specific design (height, size, security, not requiring too much muscle power). Facilities



are intensely used at rush hours (breaks). Hygiene measures are required, otherwise the improved source might create more problems than it solves. Adolescent girls need separate attention with provision of good hygiene and privacy. Facilities may be vulnerable to vandalism especially in suburban communities. There can be a rapid rotation of pupils and staff, which makes sustainable maintenance a challenge. And, of course, the costs will have to compete with other priority items in the school budget.

Before starting a selection process for the best technology solution, one should know whether there is an **existing system** and, if it is dysfunctional, what are the reasons for that. And what lessons could be learned. For a non-working system rehabilitation might be a possible option.

The final choice of technology will depend on a wide number of **factors**, including available financial resources, demand, available water sources, the physical, socio-cultural, economic and institutional environment, the existing infra-structure and other specific design criteria.

Financial Resources

1. Availability of **investment funds** (including funds from donors, government, parent contribution local sponsors, companies who might advertise on walls or tanks). For the parent contribution, the income level distribution of the parents is relevant.
2. Available budget/affordability for **recurrent costs**. One might explore the possibility to raise 'income' from the sale of water, re-use of urine and excreta, sale of advertisement space or subsidies from health insurance.

Demand

3. Defined (real) **need** (including the girls' perspective) and optional additional needs (cooking, cleaning, gardening, surrounding community)

Physical Conditions

4. Type, quantity and quality of available **water source(s)**, including seasonal variations. *For example: is the (new) water source an existing system, a river or ground water? If accessing ground water with a well or borehole is too expensive then rainwater harvesting could be a cost effective option.*
5. **Physical** environment (climate, rainfall /year, rain pattern, soils, slopes, vegetation),
6. **Building** characteristics of the schools (roof type and height, lay-out, space) and available building materials and construction skills. For example; *Trees above a school building might provide shadow and suppress high temperatures. At the same time they may encourage insects, obstruct effective rain fall for rainwater harvesting and their leaves may contaminate and block the harvesting system.*
7. Availability of a **reliable energy source**; manual/muscle power, electricity, other fuel **or** possibly a renewable energy source (wind, sun, hydropower)

Socio-cultural environment



8. **Cultural** aspects (including gender and religion) with regard to technology choice; ease of operation; user acceptance/preferences. For example; *Handpumps on wells are not easily accepted in Papua New Guinea, because women are traditionally not allowed to stand above a water source. Some Maasai prefer muddy water above groundwater and believe in the cleaning potential of the mud. The doors of latrine blocks for women should not be in the sight of Maasai men.*

Institutional

9. **Institutional** setting (standards, responsibilities, ownership of land, assets and resources, legal aspects)
10. Reparability. There should be the capacity to maintain and repair the systems either by the school staff / teachers themselves or and external **supporting skills/services** in the vicinity of the school
11. Access to **spare parts and replacements** preferable in the vicinity of the school and locally manufactured

Specific design factors:

12. The technologies used should be '**vandalism and disaster proof**' (robust, absence of loose elements, possibly raised) and respond to the local security situation. For example a *tippy tap may do in a rural setting, but is too vulnerable in a suburb (destruction or theft). In case of frequent inundations, sanitation facilities should be raised to prevent excreta floating out of the pits. Even better are facilities that can remain in use, even when flooded.*
13. The chosen technology should be **easy to use** (specifically for children) and **easy to clean**. Smooth surfaces are important.
14. Facilities should be accessible for **disabled people**. There are several good hand outs on this (WEDC, Briefing Note 1; Share/Water Aid, UNICEF)
15. The design should be chosen for **sustainability** and environmental friendliness (e.g. non- or limited use of fuels and chemicals)

Whatever technology is chosen, the most critical aspect is operation and maintenance. Some 30% of communal water points in Sub-Sahara Africa are not functioning. Essential criteria are: ownership, availability of funds, capacity and will for good operation and maintenance.

You might want to consider starting a more **centralized 'maintenance' service**, which may also be the owner of the facilities. This is especially feasible in areas with a high population density, as in the example of the service provided to over 400 schools in Eastern Cape Province (RSA) by CSIR/Kevin Wall

Good practice in water and sanitation at school is often considered to have a **demonstration purpose** to the surrounding community. Be aware that the chosen technology for schools is often different to what individual families can afford. For example



water treatment with small filters might be an option for families, but a rooftop harvesting system with a ferrocement tank is often too expensive at family level

The Water Schools programme (www.Water Schools.org) initiated by ARC is part of UNICEF's WASH in Schools initiative. There are several other programmes and organizations focused on water, sanitation and hygiene in schools and the following links can provide further information about some of them:

- 🔗 FRESH (UNESCO): www.unesco.org/education/fresh
- 🔗 WASH in schools (UNICEF and IRC): www.washinschools.info,
www.washinschoolsmapping.com
- 🔗 Plan (development organisation for children): plan-international.org
- 🔗 Save the Children (development organization for children): www.savethechildren.org

Chapter 2 and 3 explore the steps needed to make a proper choice of water and sanitation facilities and the hand washing device is included in the water chapter

Once the best facility has been identified the follow-up phases will include finalizing the design (and Bill of Quantities), budgeting and fund raising, selection and contracting of the contractor, implementation and supervision and final reporting. In the main, a consultant/construction engineer should guide this process. Tendering is usually the preferred option to get a good price/quality ratio, but 'price deals' between bidding contractors may occur so both price and quality need to be evaluated in the tender process. *In the city of Gedaref (Sudan), bidding contractors got a pre-briefing on the design, quality aspects and contract conditions and the winning contractor(s) were trained on quality standards.*

In the meantime an **operation and maintenance plan** will need to be drawn up, preferably before the final version of the design report so that it can also serve as a last check on feasibility (financial, technical and organizational). Capacity building and training will be an essential element and any arrangements with external parties will need to be established.

Before reading further the following list of pit-falls and 'lessons learned' may be useful. It was drawn up by faith schools participating in an ARC/KOEE workshop on education for sustainable development held in Nairobi, March 2012



Pit-falls	Lesson
<p>Going directly to a 5 stars system:</p> <ul style="list-style-type: none"> • High Operation, Maintenance and Replacement costs • Sensitive for failures • Not replicable in the local households • Fails when one component fails 	<p>Start from local context and take one step only (from 1 to 2 stars)</p>
<p>Improving only one component:</p> <ul style="list-style-type: none"> • For sanitation you need at least water for hand washing • Drinking water alone makes little improvement; better to first improve sanitation and hygiene (and a bit of hand wash water & soap) 	<p>Give priority to sanitation & hygiene and bit of hand wash water Drinking water can be brought by pupils as a short term solution</p>
<p>UNICEF Evaluation in schools in Malawi shows that:</p> <ul style="list-style-type: none"> • Many Ventilated Improved Pit latrines (VIP) do not work (no screen; false winds) • Many Pit latrines fail because of high groundwater tables, poor hygiene or slabs proving difficult to clean • Pits take long to fill; but when full then no option to empty • Ramps for disabled people should not be too steep (5%) 	<p>When investing in something you need to be sure that it works. Think, discuss and test with users before implementing</p>
<p>UNICEF Evaluation in schools in Malawi shows:</p> <ul style="list-style-type: none"> • That schools cannot be left alone after installing an ecosan* facility. Support is required in treatment of manure and safe application of compost and urine in the gardens 	<p>Ecosan* is a great idea, but needs long term support. Better no application than a poor application</p>
<p>Community sharing: a blessing or a threat?</p> <ul style="list-style-type: none"> • For water supply, costs can be reduced if the source (and costs) can be shared with a public system. Many schools aspire to having a separate facility, but this overlooks costs and maintenance. • For rainwater harvesting, sharing with the community can harm the effectiveness of water management of the source during dry spells • For sanitation, sharing the facilities with the community is mostly a threat 	<p>Evaluate the pro's/con's of sharing with community beforehand</p>
<p>Bias to what is known</p> <ul style="list-style-type: none"> • Most people choose quickly what they know: a shallow well, rainwater, pit latrine • There are many other alternatives that might be more appropriate (and/or cheaper) 	<p>Seek advice to find the most appropriate solutions</p>
<ul style="list-style-type: none"> • The facility is part of a chain Most people think only in terms of 'a well' or 'a latrine', but do not realise that it is also part of a chain. • For a well one should prevent the water from being easily contaminated, the water should be pumped, transported and stored. In each step it can become contaminated. • A latrine produces waste that will have a destination. For example transport, treatment, storage/dump and re-use 	<p>See a facility as part of a chain and study the entire chain</p>

* Ecosan = toilet design that enables composting of faeces and/or diversion of urine with the purpose of re-use the end product



2 WATER

2.1 QUANTITY

Basic quantities of water required for schools per day, per child and staff, as defined by UNICEF (2009):

- 🏠 1 litre of safe drinking water,
- 🏠 1-4 litre of clean water for hand washing,
- 🏠 1 litre for anal cleansing/washing (if applied),
- 🏠 1.5 -3 litre for poor flush toilets and 10-20 litres for conventional flush toilets (this can be re-used grey water)
- 🏠 For schools that provide a warm meal, extra water per child will need to be added.

The World Food Programme (WFP) recommends a minimum of 5 litres per day for drinking, hygiene and cooking, but puts the standard at 15 – 30 litres (depending on the presence of flush toilets).

For boarding schools the recommended range is 90 – 140 l/day.

Multiple water uses should be considered. If a system is designed for drinking water and domestic use, for instance, you could think about making it a bit bigger to provide water for irrigation of a school garden. This could (partly) cover operational expenses and contribute to food security.

2.2 QUALITY

Water is considered **safe** when it has no harmful micro-organisms like pathogens (e.g. E.Coli bacteria and viruses related to faeces) and when any chemical substances are within the limits established by the WHO guidelines (see table). Some of these guidelines, such as the maximum acceptable daily intake of fluoride related to body weight, relate specifically to children. Except for radioactivity, physical contamination (organic material, sand or clay) is not in itself harmful, but may reduce the effectiveness of treatment methods and may influence taste and acceptability.

Among the more common contaminations that cause water borne diseases are bacteria (E-Coli), viruses (like rota virus) and protozoa (like giardia). These organisms are disseminated via latrines near water sources, rivers, dirty hands, unwashed vegetables etc. In general the combination of hand washing, good hygiene and the reduction or elimination of harmful micro organisms will drastically reduce water borne diseases, but the idea that you can avoid them entirely is a false hope, sadly. Selection of preventive measures should therefore look at cost efficiency and include assessing the environmental impact.

Of the micro-organisms, viruses have the smallest size (0.02-0.07 micron), followed by bacteria (0.5-3 micron) and protozoa (8-12 micron). Filters that block bacteria also reduce



virus contamination but the more affordable filter models do not guarantee that sufficient viruses are eliminated. In general water filters do not fully eliminate all micro-organisms but will reduce the number. To eliminate viruses, filtering needs to be combined with chlorination or boiling but remember that chlorine will not also eliminate protozoa.

It is the concentration of harmful micro-organisms that leads to infection but a healthy adult body can tolerate much higher concentrations of pathogens than a sick or malnourished child. Drinking contaminated water is much more infectious to an empty stomach than a filled one which has created a very acidic environment so eating is recommended before drinking untreated water.

Of the inorganic chemical compounds, arsenic, fluoride and nitrate/nitrite are most common and therefore warrant the highest priority for attention.

Substance	Limit	unit	degree of harm	Remark	measurement	ease of treatment	Treatment method
E-Coli bacteria	<1	counts/100 ml	high	Measuring error could overlook about 10 counts/100 ml. Moreover, 100% sterile water is hard to get. Some tolerance could be expected.	Petri, H2S kits	easy	chemical, physical, biological
Turbidity	5	NTU	low	hampers other treatment	photometric	easy	coagulation/flocc, sedim.
Total Dissolved Solids (TDS)	1000	mg/l	low	depending the substances	EC-meter	difficult	Reversed osmosis, distillation
Electrical Conductivity (EC)	1500	uS/cm	low	depending the substances	EC-meter	difficult	dito
Acidity (pH)	6-8.5	-	low	effect on materials	pH meter/strip	easy	bleach or acid
Hardness (as CaCO ₃)			low	effect on materials, encrustation, taste; >120 mg/l is hard	strips etc	difficult	
Arsenic (As)	0.01	mg/l	high	provisional guideline, different appearances, can also be in rice and smoke	field kits, colour	medium	Coagulation, Ion exchange, prec., adsorption, membranes, biol
Calcium			low			difficult	
Chlorine (Cl ₂)	5	mg/l	high	target residual is 0.5 mg/l (Sphere)	DPD1 tablet/comparator		
Chloride (Cl)			low			difficult	
Fluoride (F)	1.5	mg/l	medium	0.2 mg/l per 10 kg body weight; also other sources (salt, food)	field kits, colour	difficult	adsorption, membranes, coagulation
Iron (Fe)	0.3	mg/l	low	only aesthetic		easy	oxydation, coagulation, membranes, biol
Lead (Pb)	0.01	mg/l	high				
Manganese (Mg)	0.4	mg/l	low			easy	Oxydation, membranes, biol, coag
Mercury (Hg)	0.006	mg/l	high	inorganic Mercury			
Nitrate (as NO ₃)	50	mg/l	medium	babies	Strips etc	difficult	Ion exchange, membranes, biol
Nitrite (as NO ₂)	3	mg/l	high	0.2 mg/l for long term exposure!		difficult	Oxydation
Silver				no harm determined			
Sodium (Na)							
Sulphate (SO ₄)	250	mg/l	low	aesthetic			
Uranium	0.015	mg/l				difficult	Ion exchange, adsorption, coag, prec

Table 1: Water Quality standards: WHO Guideline Values (UNICEF 2008 and WHO 2011)

Water for drinking and domestic use should come from an **improved source** (protected spring, covered well/borehole and (hand) pump, tap from public water scheme) or protected rainwater harvesting (in combination with treatment). An 'improved source' is, however, no guarantee for safety. A recent UNICEF study in 6 countries found that 10% of the water from taps and 30-60% of the so-called other improved sources (JMP 2010, RADWQ survey) were unsafe on the day they were examined.



Water that is safe at the source can easily get **(re-)contaminated** before it is used. This can be caused by the use of contaminated cups and container, unclean hands, or contamination from the air and insects. Water that is stored for a longer time (in tanks) may lose quality (entrance of animals/insects, algae growth, bacteria; rotting of organic elements). Tanks and vessels need to have a lid / cover and any openings must be protected with mosquito wire.

If no safe water source is available, or where there is a danger of recontamination, water should be **treated** at the point of use to reduce bacteria (and viruses). Options are physical treatment (boiling for 1 minute, ceramic filters, sand filters or UV-light), chemical treatment (chlorine or silver) or biological treatment (slow sand/biosand filters). Application of too much chlorine might be harmful. Turbid water needs pre-treatment using coagulation/flocculation, sedimentation or pre-filtration to remove the suspended particles.

Water with too high content of certain minerals needs special treatment. This is especially true for Arsenic, Fluoride, Nitrate and heavy metals but removal of minerals is often too complicated for a school application, except for some minerals like iron and manganese (through oxidation).

Remember that the water children drink at schools is only part of their daily intake.

In general the first action regarding water is making sure that it is safe to drink.



Water testing

Water quality can be tested with different methods but they are often too expensive to be used for educational purpose at an individual level. This has been used in India (<http://www.indiawaterportal.org/data/kits/index.html>) and through UNICEF in Sri Lanka following the tsunami (<http://www.irc.nl/page/38743>) using Pathoscreen.

Contamination with fecal micro-organisms is mostly tested by measuring the presence of E-Coli bacteria, usually counting the number of E-Coli bacteria per 100 ml. Cost of single tests like Hach, Millipore or Petri film vary from 2 to 5 US\$. Some of these tests simply indicate the presence of harmful bacteria while others provide a more quantitative measure and tests can take from a few hours to a day to deliver results. Regrettably the tests are too expensive to apply as a regular measurement at single schools.

The total salt content of the water is mostly tested by measuring the conductivity of the water, expressed as EC (Electrical Conductivity) in $\mu\text{S}/\text{cm}$. Instruments can do many tests and can be obtained from US\$ 30 and above. Water with an EC of 1.500 $\mu\text{S}/\text{cm}$ or more is not recommended for drinking for long periods of time.

Acidity (pH) is not so much a problem for health but does have a corroding effect on concrete and metal, especially when combined with low calcium content or the presence of free CO₂. Instruments, which can do many tests, can be obtained from US\$ 30 and there are simple test strips or other method, which cost less than US\$ 010 each.

Most other minerals will have to be analyzed in a laboratory though field indications of their presence can be obtained by the use of color strips, drip methods, colorimetric methods or others. In areas with arsenic problems, field test kits for arsenic are recommended.

In case of absence of a safe water source near the school, children can bring their water **from home** to school, so it can be treated there.

2.3 THE WATER DELIVERY CHAIN

Depending on the selected water source, the overall water delivery chain may consist of:

1. water source development and protection
2. a pumping device
3. a storage facility
4. a transport device
5. a treatment facility (central or decentral)
6. distribution
7. provision and drainage

A storage device can be used at different points in the chain and some use storage for pre-treated water or with clean, safe water. Appendix I provides the full water chain in relation to the selected water source. Try to think beyond conventional solutions: there is a lot of *literature* available on different water facilities and www.akvo.org water portal/akvopedia may be a good starting point as it contains references to a lot of literature.

The diagram below (fig1) is a nice example of a complete water chain that also includes facilities for sanitation. It is taken from Godfrey et al (2010) and comes from rural India where water use in a toilet is common despite the semi-arid conditions. While the diagram does not show some details, like pumping and treatment it is interesting to note the use of excess rainwater for groundwater replenishment.

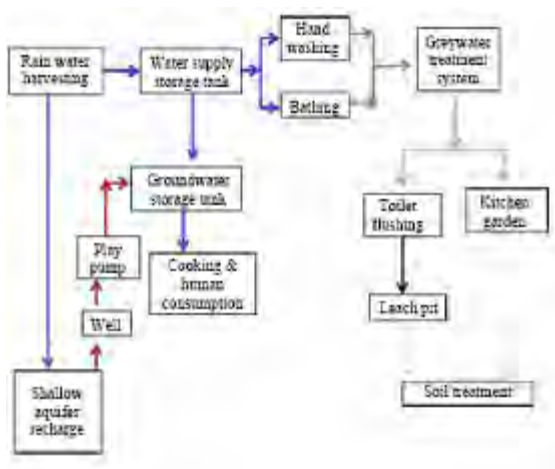


Figure 1: Example of a water supply chain from the Wise Water Management project in rural India (Godfrey et al (2010))

2.4 WATER SOURCES

Water can come from a number of sources.

The easiest source is an **existing** piped water scheme or a nearby community water point.

Surface water can be collected directly from streams or from ponds/reservoirs and go to the users through either a pumped or gravity-fed scheme. Water from such sources needs treatment and a screen at the inlet, a sediment trap, a pre-treatment unit and a point of use treatment are all recommended.

Groundwater can come from natural springs, shallow (hand dug) wells and machine or manually drilled boreholes. Wells need a cover and boreholes a cap to avoid contamination from above and both need to have aprons and so called hygienic seals to avoid contamination from the surface or ground. No water may re-enter into the borehole and, in hand dug wells, buckets are disregarded as they might contaminate the source. Manual drilling techniques can be a cheap and accessible alternative to both digging and machine drilling.

Rainwater can be harvested from roofs with gutters and also paved surfaces **before being** collected in storage tanks. This option certainly needs a sediment trap and further water



treatment can either be done in or near the storage or at the point of use with disinfection and /or water filters.

Rainwater or storm water can also be used **to recharge** a groundwater body, from where it is collected by a well. A typical example is a sand dam (which creates a sand body with groundwater), or a sub-surface dam (which block sub-surface flow in a river bed). Other options to increase water filtration in the ground might include vegetation strips along contours (Vetiver), mulching, tree planting or making so called tube recharges (small ponds with a 5 meter deep hole and a filter). This is done to increase water volumes around wells that will dry up in the dry season. More information can be found in the Smart Water Harvesting booklet produced by the Netherlands Water Partnership (NWP).

Below is a series of examples, organized according to water source. If the option is available, the following priority sequence is the most likely, but exceptions are always possible. Except for the second and third solutions (link to existing water points), the solutions are elaborated in separate fact sheets. Lifting devices, tanks and treatment options are dealt with in later sections.

1. **Gravity systems.** Connection to a nearby spring and bring water to the school by gravity with pipes. While investment cost can be high 1.000 - 50.000 US\$, depending on soil type, slopes, yield and distance, the operational costs are very low and quality is mostly very reliable. Protection of the spring area (and feeding area) and seasonal variation are points to consider.
2. Connection to an existing **Piped Water scheme** if it is reliable. Cost is mostly at a very acceptable level (0.2-0.8 US\$/m³), quality is reasonable and operation and maintenance is shared with others. Additional point of use treatment might be necessary.
3. Use of an existing nearby **Public water point**. If this is far from the school the disadvantage is the walking distance with a heavy container, especially for small children, and security may be an issue for small children and girls. A wheeled cart with containers might make it easier to supply a school.
4. **Shallow well with cover.** Disadvantage is the maintenance of pumps and the risk of contamination. Making a shallow well is difficult or impossible where the soil is too rocky or where water levels are deeper than 15 meters. Depending on the type of handpump a shallow hand dug well with a handpump costs € 500 - € 4.000. Maintenance costs are relatively low, but one should allow money for the cost of replacement(s) and any major repairs to both handpumps and concrete superstructure.
5. **Deep well/borehole.** The disadvantages are the high investment cost, risk of failure to find water at or near the school and the maintenance of pumps. Cost of a borehole with a hand or electric pump depend on depth of the aquifer and geology. Drilling through rocks is expensive - in Africa, cost ranges from € 3.000 and € 12.000 – but new drilling methods and low-cost/locally-produced handpumps can be an option in some situations. In the South of Tanzania (Njombe) school water points consist of a manually drilled borehole and a rope pump at 40 m deep at a total cost of € 650 – 800. The Rural Water Supply Network (RWSN) has a good website for guidance on boreholes and handpumps



(www.rwsn.ch). Maintenance costs for handpumps are relatively low but one should allow money for replacement(s) and major repairs.

6. **Rainwater harvesting.** This is mostly applied where there is no alternative method or to complement other systems. Apart from roof top harvesting you might also consider runoff collection, stream water collection, ponds and reservoirs, sand dams and subsurface dams. Plastic (Poly) tanks are widely available and cost about €100 per m³, excluding transport, concrete support and gutters). Prices of storage options are shown in table 2 (section 2.6). Small dams will cost easily €5,000 – €15,000 and require various additional measures.

2.5 WATER LIFTING DEVICES FOR SCHOOLS

Pumps are mounted on wells and boreholes and are applied to raise water from low tanks/chambers to raised tanks. In pump selection, it is very important to make a full financial analysis for the full life-time and to look at the servicing capacity and spare part availability in the area.

Pump types can be divided according to energy source (manual, fuel, electric, eco-powered) or to the lifting methodology. These can range from simple foot operated suction pumps, manually operated pumps like rope pumps, manual piston pumps (Nira, Indian Mark 2, Afridev, Volanta, etc) to motorized pumps, with an energy supply from wind, sun, fuel or electricity. The use of a bucket in open wells is not considered as safe, as dirt on the buckets can contaminate the water.

Handpumps exist in different types and capacities. Suction pumps can pump up water from a maximum depth of 5-7 m, which is a common depth for cisterns. Direct action piston pumps like Nira or Canzee can pump from 10-20 m (but might be heavy for children). Piston handpumps like Afridev and Indian Mark II and rope pumps can pump from 3 to 50 meters deep, and pumps like Volanta and Blue can pump from boreholes to 60-100 meters deep. The EMAS pump is designed to lift water from a well and to pump it directly to a raised tank. In general maintenance of these pumps has to be done by specialists.

If children are expected to do the pumping, special attention needs to be given to the required power, the height of the device and safety. Some projects promote the so-called 'play pump', which is a merry-go-round in which the children's play is used to pump the water. Main problems are maintenance and the safety and the 'misuse' of children to pump the water for the community, also during the weekend.

For more information on handpumps see www.akvo.org and http://www.who.int/water_sanitation_health/hygiene/om/linkingchap4.pdf

Electric pumps and some types of handpump can pump water into a **raised tank** on the roof level of the school, after which the water can be distributed to taps. For small volumes, a 'hand wing pump' might do.

Springs situated 'above' schools can use the force of **gravity**. The same might be true for stream water, but in most cases, the water needs to be pumped to a higher storage tank. Pumps and pump houses must be safe from flooding.



A special device is the '**ram pump**', which uses the force of falling water (for instance from a river) to bring a fraction to a higher level (one tenth of the water about 7 meter higher for every meter of fall).

If the height difference between pump and tank is over 50 meters, it might be necessary to have a number of pumps arranged in series. Such systems are mostly too expensive for a single school.

If **fuel pumps** are used or diesel generators, care should be taken that the fuel is not contaminating the water source.

Solar driven pumps are an expensive investment but maintenance costs will be low if the battery and panels remain in good order. Care should be taken to prevent theft of panels, battery and converter.

2.6 STORAGE FOR SCHOOLS

Water storage can serve different purposes:

1. to create a buffer between the supply and the peaks in the demand, whether on daily or seasonal basis
2. to create rest periods during the day or night for a pump or the caretaker.
3. to create (constant) pressure in taps if tanks are raised
4. to allow treatment such as the settlement of suspended particles.

There are many different tank types, from the traditional masonry and concrete ones to the cheaper ferrocement, or wire cement types, which are made with, wire, cement and local materials like bamboo, bricks or clay. These options are more economic than the traditional concrete tanks. All need skilled labour. Another option is a plastic tank of 500 to 5,000 litres, but these are (still) rather expensive and need protection against sun light. A recent development is strong plastic bags (foldable tanks; flexible tanks; collapsible tanks) as now used in Uganda. Other 'cheaper' solutions are prefabricated tanks of metal sheets, lined with plastic. These tanks can be of a very large volume and can be roofed.

It is recommended that water tanks have a wash out (to ease regular cleaning and to flush the sediments) and a regulated overflow (in case the inflow is too high) thus tanks should be equipped with entrance and outlet valves. A good quality automatic floating valve (which closes when the tank is full) is recommended, but will be costly. Openings (vent pipe, overflow and others) should be protected against insects and animals (with mosquito wire). If tank-stored water is to be used for drinking it is recommended that there should be some treatment at the outlet or a Point of Use treatment option like disinfection or filtering.



A well sealed and durable roof is the most complicated part of the tank. Experience in Kenya of roofing large volume tanks (>50 m³) has demonstrated the importance of a central column, well designed positioning of any iron bars and the importance of wet curing.

	Unit cost €/m ³	typical size m ³	
Brick plastered	10-20	0.5-1.5	
Wire cement	13-27	0.5-20	
Ferro cement	20-40	1-8	
Plastic PE	70-130	0.5-10	
Concrete	50-120	2-210	Kenya: 100 m ³ = € 6.100
foldable bags	27	1.5	Enterprise Works, Uganda
prefab sheets with lining	90-150	100-500	ex factory; Bucon; 100 m ³ ex factory NL = €12.000

Table 2: Summary of tank types and their unit prices (different sources; Africa; 2005-2012)



2.7 WATER CONVEYANCE

Water conveyance can be manually or through (closed) pipes. Manual transport requires clean jerry cans or containers that can be closed to avoid contamination and a school might develop or buy a transporter on wheels to carry the water from the source to the school.

Pipes are made of different materials (galvanized steel, pvc, polyethylene), have a range of diameters (inches or mm) and different pressure class ratings (10 meter water pressure = 1 Atmosphere = 1 PN pressure class). Not all plastics are UV-resistant (sunlight). Pipes are preferably buried into the ground to avoid damage and to prevent the risk of viruses like legionella due to water standing at high temperatures for too long. Steel pipes are much more expensive than plastic and mostly used for plumbing and when pipes cannot be buried (rocks, valley crossings).

If water conveyance is over a long distance, it is important to have wash-outs in low points and (automatic) air valves on high points. Remember that taps and most pipes cannot sustain more than 60m of water pressure (6 Atm) and that pipe walls provide resistance to water. The friction loss is to be taken into account when calculating pump dimensions or pipe diameters and such hydraulic calculations need to be done by a specialist.

2.8 WATER TREATMENT

Water treatment is required for all surface waters and sometimes for groundwater, spring water or rainwater. As mentioned, water may become recontaminated during transport and storage, which is the reason why treatment is needed to avoid re-growth of micro-organisms. One cause of recontamination in pipes can be where the distribution is done by rotation (one may get water during a few hours per day only): when there is no (or low) water pressure contaminated groundwater may enter into the pipes. Usually chlorine is applied (4 mg of free chlorine per litre) to avoid re-growth of algae and bacteria, but a newer and less well-known option is colloidal silver, which is less problematic for health (see below), but more difficult to monitor for as a residue than is chlorine.

Centralized treatment can be done by the Water Company/ supplier or there are decentralized treatment options through plants like Perfector, Water maker Naiade etc. These systems have capacities of 500 to 50.000 litres per day and need very regular operation and maintenance with more or less skilled technicians.

Turbid water needs to be pre-treated to remove the suspended particles. This can be done with 'filters' or by adding flocculants like Aluminium Sulphate/Alum, Moringa seed powder or other local products. Water that has *no oxygen* needs to be oxidized (mostly by letting it fall through the air). This may also remove excessive iron and manganese.

Disinfection technologies can be divided into:

1. **Ceramic Filters**, Examples are ceramic filter of the Pot, candle or Siphon model. Other options use membrane technology like the Perfector in large systems and Life straw family in small systems at household scale,



2. **Sand filters** combine the physical filtering of sieved sand with the biological treatment of the bio-film at the surface. Biosand filters are applied for small scale and slow sand filters for larger scale. Rapid sand filters are not meant for disinfection.
3. Other physical removal is done by **boiling** or by the application of **UV-light** (lamp or sun rays). Both are very effective in eliminating bacteria and viruses but boiling has disadvantages like cost of fuel, indoor pollution, time required to prepare, carbon emission etc
4. **Chemical Disinfectants**, The most common used disinfectant is chlorine, which is used in piped and centralized treatment systems. At the household level chlorine options come as a liquid (Waterguard, Certeza) or as tablets (Aquatabs). Chlorine can be locally made by the electrolysis of salty water (e.g. by using the WATA). There are several chlorine products, which do not affect the taste and are healthier (NaDCC-tablets/Aquatabs, Twinoxide). Another disinfectant is silver, which can eliminate all harmful bacteria but is not toxic by comparison to chlorine, does not have a smell or taste and has a long shelf life. Silver may be applied in liquid form like Silver dyne or as a floating ceramic sphere like Plation. The presence of residual silver is more difficult and expensive to measure, compared to chlorine but several companies are further developing this promising option.
5. Products that use **combinations** of the above mentioned technologies such as the Pureit filter.

Information about a wide sample of water treatment products is provided on the next page and their evaluation in appropriateness, performance and price (cost per m³ over the life cycle) is provided in table 3.

Filters like Life straw family and Pureit eliminate turbidity and practically all bacteria and viruses. Other filters like the Berkefeld, Brita, Swach and Tulip eliminate turbidity and up to 99.99% of all harmful bacteria. Ceramic pot filters eliminate turbidity and reduce bacteria by 90 -99% and biosand filters reduce turbidity and bacteria with 50-98%. New generation filters like the Tulip or Life straw family model have high filter speeds of 80 to 150 litres per day and could be used in schools. One filter would be enough for 15 to 30 children. Cost of these high capacity filters range from €9 -€30 with a filter capacity of 5.000 to 15.000 litre. As with other technologies, training in maintenance is essential. When evaluating the different options, one should also evaluate the readiness of people to use the method for a longer period.

Best/Cheap Buy	Product process, removal agent	Product name, brand	Capacity ltr/day	Unit price (in €) €/m ³	Overall AT-score *	Sub-score Performance	Sub-score Planet/People
Limited virus and bacteria reduction							
	Plation floats (ceramic silver balls)**	<i>AquaEst</i>	(50)	0.75	6.6	6.1	7.0
	Biosand filter	<i>CAWST; Hydraid</i>	100	0.11	6.4	5.7	8.0
	Arsenic reducing biofilter	<i>Kanchan, ENPHO</i>	50-75	0.11	6.1	5.3	7.0
Limited virus reduction							
BB	Ceramic Silver Pot Filter	<i>Potters for Peace</i>	15-30	0.57	7.9	7.9	8.0
CB	Ceramic/carbon candle	<i>Water4Life</i>	25-50	0.42	6.3	5.7	5.5
CB	Siphon ceramic silver filter	<i>Tulip, Basic Water Needs</i>	50-80	0.51	6.1	6.1	5.5
	Plation Rain Purification Centre	<i>AquaEst RainPC</i>	275	2.00	5.4	5.7	5.0
	Slow Sand Filter	<i>e.g. Jal-TARA</i>	(2.750)	0.22	5.2	4.4	7.0
Good virus reduction, individual-family size							
BB	Chlorine drops, hypochlorite	<i>e.g. Safe Water Storage</i>	NA	0.24	7.0	8.3	4.6
	Solar UV - PET bottles	<i>SODIS</i>	1-mrt	0.87	7.0	7.0	6.5
	Boiling (electrical; wood)		NA	17.85	6.8	7.9	4.0
	Sodium dichloroisocyanurate tablets **	<i>NADCC aquatabs</i>	NA	3.25	6.5	7.9	4.6
	Sachets flocculant/disinfectant	<i>PUR, Procter&Gamble</i>	NA	7.14	6.5	7.9	4.6
	Solar UV/IR heat, plastic bag	<i>Aquapak</i>	5	3.13	6.4	6.1	6.0
	Iodine & micro-filter in suction 'straw'	<i>Lifestraw, Vestergaard</i>	1 (max 10)	4.08	6.4	6.1	6.3
	Iodine & ultrafilter, gravity	<i>Lifestraw, Vestergaard</i>	15 (max 150)	0.79	5.3	4.9	5.2
	Carbon, filter, chlorine	<i>Pureit, Unilever</i>	20	4.35	5.1	5.3	5.0
Good virus reduction, group size							
CB	Multi-filter and UV	<i>Perfector-E, Norit</i>	32.000	0.69	6.2	6.6	6.0
CB	UV-(solar PV energy), macro filter	<i>Naiade, Clean Water Now</i>	2.000	0.59	5.8	5.7	6.5
	Ultra-filter; hypochlorous (electrolyse)	<i>WaterPurifier</i>	600	1.21	5.7	6.1	5.0
	Chlorine production (electrolysis)	<i>WATA (mini)</i>	(4800)	0.02	4.9	5.3	5.8
	Quality distribution	good/green	green	6	7	7	7
		medium/orange	orange	9	9	9	6
		poor/red	red	6	5	5	8

* The overall AT score is using the weight of the criteria and is not by definition the average of the sub-scores

** Post treatment application only

Table 3. Example of Product comparison table

BB = Best Buy (very good performance (all >6.5) and within price level of € 2/m³)

CB = Cheapest Buy (low price level at acceptable appropriateness level (all sub-scores >5.5))



The selection of treatment technologies for schools is dependent on a number of factors:

- 🔍 type of water source, its water quality and the variability of turbidity
- 🔍 the need for pre-treatment to reduce turbidity for more effective treatment
- 🔍 the need for reduction of specific chemical compounds (e.g. iron, arsenic, fluoride, nitrate)
- 🔍 the need for reduction of biological contamination (bacteria, viruses, helminthes)
- 🔍 the choice for a centralised or decentralised treatment
- 🔍 financial, technical and cultural factors

For financial reasons, it may be necessary to separate ordinary non-potable water from taps and specially treated water for drinking. This requires good education and sufficient warning information at any water points with non-potable water.

Taste can be improved by the use of activated carbon. Filter brands that use this are for instance Korean king, Berkefeld, Stefani, Brita and Tulip.

Some *inorganic chemical elements* can be easily removed, but most of them need sophisticated devices and hence skilled staff. Special care should be taken with Arsenic, Fluoride and Nitrates.

For more information about disinfection see Smart Disinfection Solutions

Remember, much can be done by *prevention*. This can be done by ensuring the full coverage of spring box or well heads and the avoidance of entry of drainage water into the water source. For rainwater a sieve and a first flush device are needed before the water enters the storage tank. Tap water should be collected in safe jars, jerry cans or other containers, which can be closed.

2.9 WATER PROVISION

The way the water is given to the children is important and should guarantee that no contamination can take place. Education and monitoring are essential in this respect and these are a few observations/ suggestions:

- 🔍 One option is to provide drinking water in a canteen or in the classroom and have one vessel/container per class of which it is clear that it contains water for drinking only, and is seen as precious (and may be holy).
- 🔍 Pupils should be prevented from touching the water with hands or dirty cups. This can be helped by using storage tanks with a lid and a tap or by using bottles or a kettle. Using a ladle or spoon to take water from a container is not recommended as this may easily become contaminated in a school environment.
- 🔍 Ideally, each pupil has its own cup or plastic bottle, which is regularly cleaned. If there is only one cup, this needs to be cleaned with hot water, soap and a clean brush after each use.
- 🔍 It is best to keep the drinking function separate from the other functions of water, like toilet units and hand washing, because these other devices get easily contaminated.
- 🔍 Pupils should be discouraged from drinking straight from a tap, or using their hands as cups.



- ☞ Care is to be taken not to waste water - a dripping tap can drain a full tank, even if it looks minimal.

Hand washing facilities are very important for improved health in schools. Hand washing with soap can be more effective in reducing diarrhoea than a safe drinking water facility and a sanitary unit. Hand washing with soap needs to be done after a toilet visit, before food preparation, before eating and often after eating. Although hand washing is more related to the subject of hygiene, we include it in the 'water' chapter, as it needs to be integrated with the water supply facility.

A few observations:

- ☞ The hand washing location is preferably near the toilet but there should also be a facility near the school building so that hands can be washed before eating.
- ☞ From a monitoring perspective, the hand washing device is preferably positioned outside the building structure, but for small children a hand washing device near the classroom is recommended.
- ☞ The size and ease of use of the facility should take into account that younger children need to be able to use it. Having an optional step near the device might help this.
- ☞ Do not use 'one bowl for all' but ensure instead that clean water is used every time.
- ☞ Recontamination of fingers/hand may take place by retouching the tap with the fingers or by using a shared towel so these should be avoided. Teach children to close the tap in a different way (e.g. using the back of the hand or the elbow), or by the use of alternative designs (automatically closing taps, constant flow, taps that can be manipulated by elbow, knee or foot). There are some very simple self-closing devices like Tippy taps which are opened by the feet.
- ☞ Drainage is very important. Children will be discouraged from using the tap if they have to step into mud.
- ☞ Great care needs to be taken to avoid wasting water. One good idea is to use a tippy tap, which is very economic in water use.

Hygiene and hand washing will often have a religious connotation and function. If the religion describes certain practices, this should be incorporated into the design of the water provision, and such practices can be used and explained in the hygiene education.



2.10 WATER TECHNOLOGY SELECTION

The following steps are recommended in selecting a water facility for a specific school.

Step 1: Remember to consider both water that is safe to drink and water to be used for hand washing. Determine the **water quantity** per pupil per day and per year; Distinguish two options: (A) the minimum option for drinking and limited other use like hand washing (2-6 litre/pupil/day) and (B) the most desirable option which includes water for cleaning, cooking, toilets etc.

The minimum option is essential if one has to rely on rainwater or water supplied by tankers.

Step 2: Make an inventory of **all the potential options** in the vicinity of the school: this might be a public water scheme, nearby public improved water point, shallow groundwater, deep groundwater, stream or pond, rainwater harvesting. If there is an old supply, the rehabilitation of the old system should be included as an option.

Determine for each source the possible **quantity** (does it match outcome of step 1?) and the **quality** (is there a need for treatment regarding physical, chemical or biological contamination?).

The table below provides a rainwater harvesting calculation of the once in 10 years minimum daily water availability for a school of 200 users, having 1.5 m² roof per pupil and having different rain characteristics. From this table one can evaluate whether rainwater harvesting is feasible. It is quite clear, that for boarding schools, the rainwater option is not very feasible.

rainfall			pupils& teachers	roof area	efficiency**	Availability
mean annual	variability index *	once in 10 years minimum				Once in 10 years minimum
mm/yr	%	mm/yr		m ²	%	l/cap/d*
500	40%	300	200	300	65%	1,46
750	35%	488	200	300	70%	2,56
1000	30%	700	200	300	75%	3,94
1250	25%	938	200	300	80%	5,63
* variability increases with aridity						
** efficiency increases with rainfall (in arid situation, a lot is evaporated/lost before reaching the tank)						
*** 200 school days in a year						

Table 4: Example of school water need calculation and feasibility of roof top rainwater harvesting

The required (minimum) storage volume can be calculated from the once in 10 years maximum length of the dry season in days, multiplied by the school day factor (200/365) and further multiplied by the average daily availability times the total number of users. In case of a mean annual rainfall of 750 mm and a once in 10 years dry season of 8 months,



*the required volume is $8*30*200/365 * 2,56 * 200 = 67,330$ litres or $67 m^3$. Rationalization is required, right from the beginning.*

Depending on the depth of wells or boreholes, handpumps supply 300 – 2.000 litre/hour (15 – 100 buckets of 20 litres), but one should realize that the power of children is limited and time elapses between the filling of buckets (including rinsing). 300 – 600 litres is more realistic in this sense. The time lag is also valid for taps, which mostly have a rather limited yield.

Step 3: Select a maximum of three preferred alternatives from a water source perspective. In cases of scarcity of water or limited funds, identifying separate sources for drinking and other purposes might be an option.

Step 4: Determine for each selected alternative the **full chain from source to mouth** (water source development, pump/lifting device, transport, storage, treatment, provision, drainage). The position in the chain can be different: for example, water treatment may happen before storage or even before transport; pumping may be after storage etc.).

Table 7 shows a matrix of possible chain elements/needs for each source type. You should also include the links to sanitation, hand washing options and other desired uses.

Step 5: Determine for each part of the chain the most realistic choices.

This might be a complex exercise. It should be limited to technologies that are available in the area of the school as it is unwise to try technologies that are unknown in the area or innovations in isolation unless you are working with a large school programme or project. For instance if a school is situated in an area with ground layers where manual drilling is possible and water layers (aquifers) are expected to be less than 40 meters deep, hand drilled boreholes and simple handpumps like a rope pump could be an option. However, if there are no local skills to do this then a programme is needed to train local technicians and workshops in these technologies before work can begin. Similarly for water treatment: if chlorination or ceramic filters are an option but there is no supply chain of spares, this chain first has to be developed. For each part of the chain, one should consider the criteria/factors under chapter 1 and the general issues under section 2.2.

In some areas, specific technologies are not allowed by the authorities. In Zimbabwe, groundwater may not be used from wells in urban areas. Also many water treatment options need to be approved (certified) by the local authorities.

The water portal site at [akvopedia \(www.akvo.org\)](http://www.akvo.org) provides information about many technology choices under the headings 'water access', 'pumps and distribution', 'storage and recharge', 'treatment and tests' and 'irrigation and other uses'. For sanitation, there is a ready-made web based decision support tool at www.akvo.org. Such a supportive tool is not yet developed for the full water chain. Rain Foundation has made a beginning for rain- and storm-water and Aqua for All/Akvo have begun to develop a tool for treatment options.

Step 6: Determine investment costs and operational costs and express them in €/litre or €/m³ and in € per pupil per year.



Mind that there are several new cost-effective solutions, which can be more effective and cheaper than more traditional methods: for instance, instead of hand digging or machine drilling, one might consider manual drilling methods. If expertise is not available programmes are needed to create that expertise. In the past heavy duty handpumps (like India Mark II/III or Afridev) have been put on wells with shallow groundwater but there are now cheaper alternatives, which are also lighter to operate and more easy to repair. These include suction pumps like Jibon or Treadle pumps for water levels up to 5m deep as well as direct action pumps like Nira, Canzee, Mark 5 for water levels up to 12-20 meters, although at 20 meters they might be heavy to operate. For water levels up to 40 meters deep, locally produced rope pumps can be used, but are not fit for very intensive and uncontrolled use.

Sometimes, it may be more cost-effective to invest in very robust and high quality technology in order to reduce the maintenance costs. This is especially true for handpumps at deep water levels. *For middle deep boreholes up to 50 meters pumps like Afridev and Indian Mark 2 are advised and for deep boreholes, high quality pumps like Volanta and Blue are advised as they can pump from boreholes down to 100 meters deep. Spare part delivery and qualified technicians are critical factors.*

There are also very low cost technologies available for water storage and water treatment.

*See Smart Series on water harvesting and disinfection**

Cost	Unit	Evaluation	Remark
Lifetime	year	5	
capacity	l/day	50 - 80	
Volume in lifetime	m ³	35	5 filters * 7 m ³
Investment	€	€ 8,00	€ 7 - 9
Replacement during lifetime	€	€ 10,00	5 * € 2/year
O&M lifetime	€		none
Salary cost Lifetime	€		none
Unit price	€/m ³	€ 0,51	€ 0,49-0,54

Table 5: Example of a cost calculation for water treatment with a Tulip Siphon Filter for its full life cycle:

Step 7: Together with teachers, parents and local experts evaluate the best water source option. This will be a balance between the ideal solution and the financial ability for investment, use, maintenance and replacement. Be sure that you have looked at the entire chain and remember that a solution for both community and school can have many advantages.

The relative higher investment in the shallow well option in appendix II is easily compensated by the lower unit costs per m³, due to the higher volume of the water source.



Rainwater in this example is only attractive if little water is required, or if wells or boreholes have disadvantages, like high cost, risk of lowering water table, water quality/taste, taboos or cost of maintenance.

Roof top harvesting can be considered as a back-up option for the other sources, but is mostly too costly as a sole water source. Harvested rainwater is often used for hygienic purposes only.

	Unit	Evaluation	Remark
Lifetime	year	10	
Capacity	l/day		
Volume in lifetime	m ³	400	4 * 10yr * 10 m ³
Investment	€	€ 1.000,00	incl gutters
Replacement during lifetime	€		NA
O&M lifetime	€	€ 200,00	cleaning
Salary cost lifetime	€		NA
Unit price	€/m ³	€ 3,00	

Table 6: Example of cost calculation of rainwater tank with 4 fills per year and no treatment

Step 8: Define with the most relevant stakeholders for the selected chain elements the most relevant design parameters that come up from the discussions (related to target groups, age level etc.) and hand these specifications/list of preferences to a design engineer.



Table 7: Water Source Options and likely chain for school water supply

	Condition	Chain					Treatment						Provision	Drainage	Remarks alternatives
		Source	Collection	Lifting	Transport	Storage	Turbidity	oxydation	Organic/disinfection	mineral reduction	Taste	posttreatment			
FACTORS		Quantity, Quality, depth, distance, protection	protection; pre-treatment; efficiency	energy source; maintenance	pipes, manual, tankers (clean)	volume, price (material), land, height			group or individual; filter; UV; chem; heat	pre-test; or local know-how	culture;		water saving; hygiene;		
rain rooftop	hardened roof/surface; >400 mm/yr		gutter, first flush	Rare; only with subsurface tanks	Rare	Tank; above or subsurface	Rare	Rare	Preventive	No	Carbon	yes	tap at tank; or pipe>tap	attention	fog nets; electrical device
rain protected surface	land, rain, protection	protection	sand trap	optional; manual or energy	optional; pipes or manual	subsurface tank	yes	no	yes	No	Carbon?	yes	Mostly lifting; some gravity	prevent return flow in tank	rock catchment
spring	No inflow of surface drainage; pref above school	protection	small chamber	optional; energy driven	pipes or manual	If yield is low; tank for night inflow	Rare	Possible	Rare	Possible	Possible	Rare	taps at source or at school	attention	
public scheme nearby	reliability (daily and quality)	x	connection	x	pipes	if pressure fluctuates	Rare	Rare	Possible	Rare	Rare	possible	taps	yes	
nearby public water point other than tap	improved type; otherwise improve!	improve; rehab (cap; disinfect)		see wells	manual; or pipe to overhead tank	containers (or overhead tank)	Rare	Rare	Possible	Possible	Possible	Rare	manual or tap linked to overhead tank	possible	
shallow groundwater	sanitary seal; clay above sand; protection to overland flow	dug wells or drilled wells; local knowledge	radial tubes?	manual/electr; suction/push;	manual; or pipe to overhead tank	containers (or overhead tank)	Rare	Possible	Possible	Possible	Possible	Rare	manual or tap linked to overhead tank	around well	recharge enhancement
deep groundwater	positive indication from survey	drilled wells	good filters	see above; deep water level	manual; or pipe to overhead tank	containers or overhead tank	Rare	Yes	Rare (after poor transport)	Possible	Possible	Rare	manual or tap linked to overhead tank	around well	
permanent stream/pond	good access; flood protection		protected intake; sediment red; chamber	possible	pipes	Common	Yes	No	Yes	Rare (in case mining or industry)	Possible	Yes	tank and taps	yes	bank filtration
intermittent stream	combine with recharge, retention, wells	sand or subsurface dam; bank filtration	mostly with well; may be drain	see shallow grw	see shallow grw	see shallow grw	Rare	Rare	Common	Rare	Possible	Possible			



Table 8: Example Cost evaluation of selected water supply options

	Condition	Chain										Provision	Drainage	Remarks alternatives		
		Source	Collection	Lifting	Transport	Storage	Treatment									
FACTORS		Quantity, Quality, depth, distance, protection	protection; pre-treatment; efficiency	energy source; maintenance	pipes, manual, tankers (clean)	volume, price (material), land, height		Turbidity	oxydation	Organic/di-infection	mineral reduction	Taste	posttreatment	water saving; hygiene;		
selected option																
roof top with treatment	roof existing: 100 m2	roof	gutters	na	12 m pipe & fittings	20 m3; 1 m raised	NA	NA				coal filter	silver balls	tap s	minor	TOTAL
particularities		existing	25 m		PVC-75UV resistant	cleaning & disinfection each year										
Lifetime (year)			7		10	10						5	0,25	20	20	
filling cycles/yr						4							4			
Capacity (l/day)																
Volume lifetime (m3)			560		800	800						400	20	1600	1600	
Investment (\$)			50		20	1000						20	0,6	20	25	\$ 1.136
Replacements during lifetime (\$)			15		15							20		21		
Energy lifetime (\$)			0		0	0						0		0		
O&M lifetime (\$)						10						0		0	10	
Salary costs lifetime (\$)						200						50		30	50	
Unit price/m3			\$ 0,116		\$ 0,044	\$ 1,513						\$ 0,225	\$ 0,030	\$ 0,044	\$ 0,053	\$ 2,02
			6%		0%	2%	75%		0%	0%	0%	0%	11%	1%	2%	3%
selected option																
shallow well with 5 drinking units and chlorine drops			well 1,5 m diam, 15 m deep	hand pump, IM-IV	NA	Vessel at school; 5 of 20 l	NA	NA	Cl drips	NA	NA	NA	buckets with tap	in well	TOTAL	
particularities			soft soil						1 drop per 20 l							
Lifetime (year)			15		7	5								5		
filling cycles/yr						3259								3259		
Capacity (l/day)			2000		2000											
Volume lifetime (m3)			6.518		3.042	326						0	0	326		
Investment (\$)			3000		1200	35								40		\$ 4.275
Replacements during lifetime (\$)			0		60											
Energy lifetime (\$)			0		0	0						0		0		
O&M lifetime (\$)			0		25	0						0		0		
Salary costs lifetime (\$)			0		200	0										
Unit price/m3			\$ 0,460		\$ 0,488	\$ 0,107								\$ 0,123		\$ 1,18
			39%		41%	0%	9%		0%	0%	0%	0%	0%	0%	10%	0%



3 SANITATION

3.1 INTRODUCTION

Sanitation is about more than simply a decent toilet. Effective sanitation means the avoidance of contact between human beings and dangerous micro-organisms (pathogens) to prevent the spread of diseases, like diarrhoea.

According to UNICEF the basic sanitation requirements for a school are (UNICEF 2009):

- 🔹 maximum 75 children for each toilet (target is 25 girls per toilet, 50 boys per urinal (of 1 m), 50 boys per toilet if there is a separate urinal)
- 🔹 separate toilet blocks for boys, girls and school staff (facilities regarding menstruation)
- 🔹 for each block there is at least one toilet for disabled (wider door and room, ramp, support)
- 🔹 distance between school and toilets maximum 30 meters
- 🔹 hygienic hand washing facilities with soap.

The unit figures may be higher if children can go to the toilet during class hours, when the breaks of class hours are not all at the same time, or when the school period during the day is relatively short.

For schools, special attention needs to be provided to the design for **small children and disabled people** (size, ease, security, muscle power, attractiveness) and to adolescent **girls** in their period of menstruation (private place for hygiene and washing of clothes or disposal of napkins). Also teachers should preferably have a separate toilet. A good balance needs to be found between having sufficient distance between school building and sanitary unit (30 meters), visibility of the pathway and the need for privacy. One in five poor people are disabled so consideration must be given for adapted designs for **disabled pupils**, whether visually impaired or physically disabled. Any school having no such students can indicate that the school is not receptive for this group. When it comes to considering sanitation, there are many taboos and the subject is very personal so it is vital to include children, parents and teachers in the design process.

For sanitation, it is important to design for the **full chain** from secure access to final destination, whether subsurface storage or **re-use** of manure and urine. Waste can be seen as a 'source' for other activities, like the production of biogas, manure and nutrient supply for agriculture, carbon for briquettes and feed for fish ponds. Sanitary systems in a school environment can be of a sufficient scale to exercise such innovations and it is important to have qualified staff to deal with this.

The construction of **urinals** needs to be considered and in some countries, even girls' urinals are available. Not only does this support the idea of re-use of urine, but it also reduces the pressure on the more expensive and time consuming common toilet facilities and urinals are



easier to maintain and clean. Remember that, for younger children, the height of urinals needs to be appropriate and that it is not the habit among boys to squat when they urinate.

The sanitary provisions in the school environment may challenge the children to change their habits and behaviour, which might have a wider impact on their families and society as a whole. The school facilities may thus function as a **demonstration**, but at a family level such arrangements are often difficult to afford so the teaching of children and parents should also include realistic alternatives for household level.

When selecting their solution, people often aspire to the highest standard, especially if external funding is available. From our perspective, sanitary solutions need to fit with the local environment, and it would not be appropriate to build a 'toilet palace' next to a school with a leaking roof, or worse. It is also very important to consider recurrent costs, as flush toilets require high operational costs. But, on the other hand, a higher quality installation might actually reduce maintenance and repair costs in some circumstances.

The 'sanitation ladder' might provide a guiding tool in choosing sanitary facilities for your school. By defining different levels from a simple pit latrine to a flushed toilet and everything in between it is possible to climb the ladder step by step rather than jumping onto the highest step in one go. (see step 4 under section 3.3).

3.2 THE SANITATION TECHNOLOGY CHAIN

The sanitation chain consists of the following possible elements:

1. Toilet facility (what's above the ground)
2. Collection and storage; in situ treatment
3. Conveyance
4. External treatment
5. Re-use/disposal

The **toilet facility** includes the design of the building/structure and the choice of type of toilet.

The different types of conventional toilets are pit latrines (including ventilated improved pit-latrines), pour flush toilets (limited water use, especially where it is common to do anal cleansing with water) or flush toilets. The latter consume a lot of water and need external storage and conveyance. They are discouraged in most developing countries, especially in case of water scarcity.

Ecosan toilets are oriented towards the re-use of the human waste. Most common are composting toilets, but the separation of urine and excreta is becoming more common. For composting, the use of some detergents is not recommended, as the 'good' germs should not be killed. A simple ecotoilet is the arboloo; this is a dry pit latrine with a movable superstructure.



The *form of the toilet unit* should be adapted to the local circumstances, whether just a hole with foot supports (often prefab or under the name sanplat; with or without urine diversion), a floor receptacle for pour flush toilets or a raised toilet. The toilet should have a cover/lid. The hole should not be too wide, especially not for small children. Raised seats might have a flexible seat: one with a larger and an inner one with a smaller hole. A grip next to the seat/hole is recommended for small children. Attention is to be given to disabled pupils and special girls' needs.

The use of *urinals* is encouraged, even for (younger) girls. In some cultures, a shared urinating wall is accepted; in others the urinals should be private and individual. Height is very important for minors. They need to be cleaned at least twice a day but frequent flushing with water is not required and non drinkable water may be used for cleaning.

The *superstructure* of the school toilets needs to be robust, roofed and well ventilated and privacy is to be protected. Some specific structural points:

- 🔹 The accessibility for insects and animals should be prevented as much as possible.
- 🔹 When doors are applied, special attention is to be given to locking (from inside) and the strength of hinges. They should be wind proof but not too heavy for younger children. *When visiting a project in Kenya, all the doors of the latrines were damaged and on inspection it was found that the carpenter had used nails instead of screws. Moreover, when the doors were blown open by the wind momentum was created that applied 20 times more force on the nails/hinges, which were then easily wrenched out of the doorframe.*
- 🔹 Special attention is to be given to the stability of the structure and its foundation, recognizing that the presence of the pit nearby might provide instability.
- 🔹 The use of wood/bamboo at floor level needs to be avoided and if wooden frames are used, they should be based on raised stone/concrete pillars. Wood should be well protected (by oil or paint).
- 🔹 Floors need to be designed to be easily cleaned - including the lowest drainage point.
- 🔹 In choosing a design consider any possibilities for cost saving by the use of alternative materials or design.
- 🔹 Where there are risks of flood or inundation, the full toilet structure needs to be raised to avoid the entrance of flood water into the building.
- 🔹 Have separate compartments for boys, girls and teachers. Remember that girls need more space behind the seat/hole than boys.
- 🔹 Have a 'dust bin' at every toilet unit and next to the hand washing facility
- 🔹 Include a hand washing facility in the design
- 🔹 Consider the use of urinals, urine separation devices or Ecosan



What makes latrines accessible for disabled people?

Each latrine block to have one accessible cubicle with:

- ◆ additional space (at least an extra 1m²)
- ◆ wider door (minimum 80 cm wide)
- ◆ hand rails for support attached either to the floor or side walls
- ◆ raised toilet seat, preferably fixed
- ◆ an access ramp ideally with a gradient of 1:20, but if space is limited, maximum gradient 1:12.

WEDC research shows that the additional cost of making a school latrine accessible is less than 3% of the overall costs of the latrine.

(source: WEDC 2011 Briefing Note)

The **collection and storage unit** will vary from the simple pit below a pit latrine to a composting compartment and a septic tank or a combined wastewater treatment unit. For urine, a separate collector (jerry can or container) can be used. Urine can be useful for watering the school garden and, as it has 5 times more phosphate than faeces, it can sometimes be sold to neighbouring farms. The pit/tank may be situated below the superstructure or next to it; in which case, the gradient of the drain should be more than 1:12. For septic tanks, there should be an entry for emptying and that point should have an easy access for a vacuum truck. Pit latrines may have a double vault compartment. When one compartment is full, the other is put into use (by closing the seat or by changing the drain). Double vault systems only work if the non-used compartment can remain out of use during one full year after which time the slurry might be used as manure in orchards.

In case of **Ecosan**, most collectors are *above the ground*. If containers are used, they should not become too heavy for handling and be positioned safely so as to avoid human contact. Composting toilets (or dehydrating toilets) have dark painted sun oriented inclined covers. In flood prone areas, a raised latrine with a raised pit is recommended but in this case, rising 'groundwater' levels may lead to the overflow of pits. A raised superstructure may also be needed in case of a rocky sub-soil or where the sands are too loose for pit stability. Ecosan toilets, using both urine and faeces, can be considered but in practice this is more complicated and there may be more cultural resistance to their use.

More sophisticated systems such as an anaerobic filter, an anaerobic baffled reactor or an anaerobic biogas reactor combine storage and treatment.

The Wise Water Management project in India developed a model for re-use of grey water for toilet flushing. The grey water comes from the hand washing and bathing in the sanitation

facility. It is lead through a pre-filter (sponge) to absorb the soap and hairs, before going on to a baffling tank for sedimentation, and two gravel/sand beds for further treatment, finally followed by some form of aeration. The water in the collection tank is used for gardening and toilet flushing. Each week, the collection tank is disinfected with chlorine.

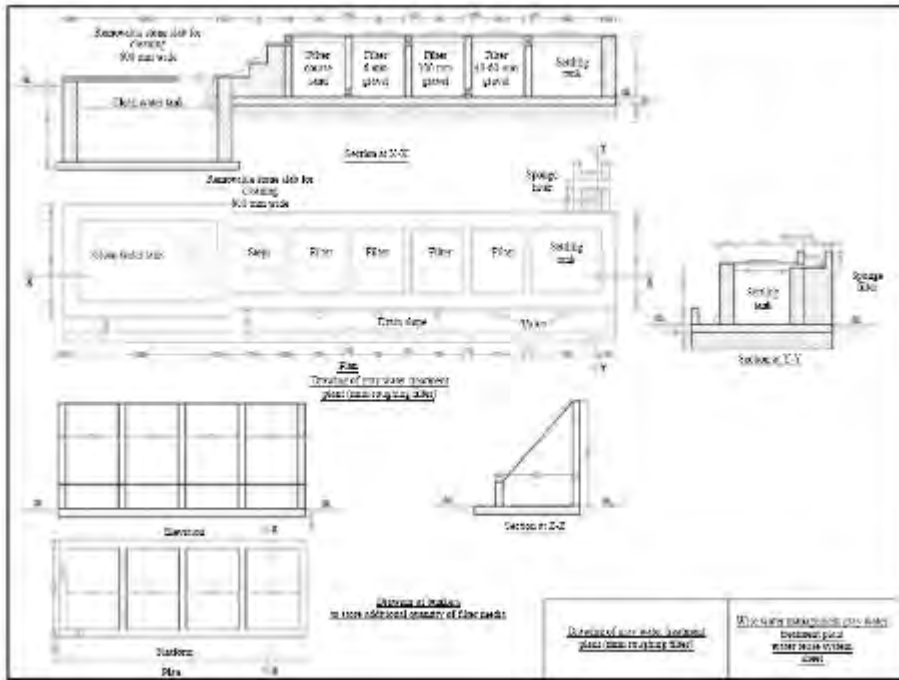


Figure 2: technical drawing of grey-water treatment in the Wise Water Management project in India (Godfrey et al 2010)

The water is filtered at $0.2 \text{ m}^3/\text{m}^2 \text{ h}$ through a gravel bed of 10-20 mm and one of 6-10 mm. The removal efficiency for most of the contamination factors, including turbidity and E.Coli, was around 50%.

The *selection of the volume* of the pit or tank will determine the life cycle or frequency for emptying (see 3.1). An adult living on an almost vegetarian diet produces about 145 litres of excreta per year and 400 litres of urine. For a meat diet, the weight of excreta is much lower and for children in a school situation, these figures will be lower still. Taking into account factors like the 5-day week, holidays, a child's much lower food consumption, avoidance of toilet use during school time and short period of the day we estimate that a school toilet will need to deal with around 15 litres of excreta and 60 litres of urine per schoolchild per year. Any material used for anal cleaning and hygiene pads/napkins for adolescent girls, if dropped into the hole, should be included in the calculations though, ideally, non-degradable materials should be put aside in a separate (covered) collector that is regularly emptied. This separation, combined with access for desludging, will enlarge the life time of a pit and reduce the need for change of location



It is usually recommended that you *seal the walls* and floor of pits to prevent contamination to groundwater but in most cases subsurface drainage water is clear of bacteria within 60 days. As the composting process is more rapid under dryer conditions then it is only where there are water wells nearby or the groundwater table is very shallow, that sealing is recommended.

Septic tanks can also be designed as biogas generators.

Pits (and tanks) may have *vent pipes*, which need to be screened to trap insects flying towards the light and to prevent entrance of animals. Vent pipes in Ventilated Improved Pit latrines need to be at least one metre above the roof, 90-150 mm in diameter, black painted and sun-exposed. Some experts question the effectiveness of VIP-latrines, nowadays.

The **conveyance of slurry** (and urine) from pits may be done through sewers, vacuum trucks or by transport using containers, though the compost from composting toilets can be removed safely after one year without further precautions. Human contact with fresh slurry needs to be avoided and protective clothing must be worn when anyone is involved in slurry conveyance. The overflow from septic tanks can be collected using a system of small diameter pipes and for larger schools or boarding schools the pre-treated overflow of the septic tank may pass through a constructed wetland or helophyte plant filter before safely replenishing a fish pond.

Re-use of urine and excreta needs specialist advice and good coaching. Urine in general has no bacteria, is relatively harmless and can be used the same day it is produced. Excreta however is full of harmful bacteria (E Coli), needs to be treated with care and composted for at least 4 months before it can be used. Urine and excreta can also be used to produce biogas, which could be used in the school kitchen or for lighting the building while pathogen-free manure can be re-used in the school garden and pre-treated waste water can be used in fish ponds. There is a lot of literature on this issue, which goes beyond the purpose of this handbook.

Many schools are developing tree nurseries but it should be borne in mind that newly planted trees can grow quickly and their roots can easily destroy buildings and structures, including underground pits.

For **boarding schools**, the standards need to be higher with regard to sanitation blocks and water availability for hygiene and sanitation. Similarly higher standards apply to washing, laundry and shower facilities and the provisions made available for sick children.

Investment Costs are in the order of € 1.000 per seat and € 20 per child, excluding water supply facilities, hand washing facilities and hygiene education. There is a wide variation and the unit prices are heavily dependent on the number of users. The table below shows a summary of the database of Aqua for All supported school sanitation projects. The difference between minimum and maximum is huge. Some projects have a simple series of pit latrines and others have complicated eco-san with biogas.



	cost per seat			cost per pupil (max 75/seat)			Source A4A
	min	average	max	min	average	max	
Asia	€ 88	€ 894	€ 1.389	€ 4	€ 16	€ 27	1202 seats, 9 countries
Africa	€ 285	€ 1.003	€ 3.036	€ 5	€ 20	€ 40	1491 seats, 11 countries

Table 8: Summary of sanitation infra-structure investments at schools (source: Aqua for All data base; water facilities and hygiene mostly not included in price)

3.3 SANITATION TECHNOLOGY SELECTION

In designing the sanitation facilities, the following **steps** need to be taken, preferably in a consultative or participatory process with children, parents and teachers. Be sure to include a good gender balance: for some taboo issues, it can be essential to work separately with male and female groups. The steps below are mainly derived from a Decision Support Tool, developed by WASTE and AKVO.

Step 1: decide on the **design criteria** including the maximum number of users, the division of groups using the facility and for each group any specific aspects around access, safety, hygiene, privacy etc. as well as the final destination of excreta and urine. It is good to start by considering your experience of any existing system you are using or a known system from another school. In thinking about design criteria you should also evaluate whether eco-sanitation, urine/excreta separation or other types of re-use might be an option.

Step 2: calculate, for **size estimation** purposes, the number of users (gender and age specific) and the volume of excreta and urine produced per day/per year or per emptying cycle.

Step 3: Determine possible **limiting factors** with regard to soil/rock, risk of inundation and available space and identify possible **sites** for the sanitary units and possible storage and treatment installations. Remember that sanitation blocks should be at least 20 m from a (groundwater) source and 1.5 m above the groundwater table. If there are prevailing winds you should consider the most suitable location in terms of any odours. The web-based Decision Support Tool of Waste and Akvo (www.akvo.org – sanitation portal) provides a short list of relevant factors you might need to consider, including availability of water, soil type.

Step 4: Define the **desired situation** if money was not a problem and then identify the **'intermediate' steps**, which might be more affordable and acceptable. A school with only 1 latrine for 50 boys and 50 girls could aspire to a concrete sanitary block with 3 flushed toilets for girls, and 1 urinal and 1 flushed toilet for boys. A positive and realistic intermediate step, however, may be to build two more pit latrines: one extra for girls and one for boys.

Step 5: Enter into the **design evaluation process** for each part of the chain, namely: the 'toilet'/superstructure, the collector, possible transportation/conveyance of waste, possible treatment and possible re-use. The web-based Decision Support Tool developed by Waste and Akvo (<http://waste-dev.akvo.org/>) can help you in this process. Possible further options can also be found on the sanitation portal of the Akvo website.

Step 6: Make a choice from your selected sanitation chain options, based on technical, economic and cultural criteria and using feasibility criteria (see chapter 1).

Step 7: Define with the most relevant stakeholders for the selected chain elements the most relevant design parameters (related to target groups, age level etc.) that have been identified during the design discussions and ensure that these specifications/list of preferences are handed to the design engineer.



Example of a sanitation chain with a diversion toilet, separate storage for excreta and urine, transport of tanks, composting and re-use of manure and urine (source: www.akvo.org).



4 HYGIENE

Hygiene is inevitably linked to water and sanitation as a means to break the transmission of dangerous micro-organisms from faeces to mouth through dirty fingers, flies, food, floor (soil) and fluids (water). Sanitation reduces the first contact, water treatment reduces the transmission line through water and hygiene reduces transmission through other paths. Hygiene education and effective use of hand washing facilities are 7 times more effective for good health than improvement of water supply (*3IE, 2009*).

Hygiene can also be a link to other aspects affecting physical well being, such as health, nutrition, body hygiene, sexuality, environment and housing/habitat but all these different aspects cannot be considered here. Prevention strategies such as cleanliness, health checks and vaccination is very important, as is health treatment, including very cost-effective deworming campaigns, and improved clothing and foot wear.

Improving hygiene is mainly achieved through education leading to behavioural change, thus most literature on hygiene concentrates on educational methods. Relevant value-based education relating to faith and culture is another major focus of the ARC Water Schools programme.

Positive hygienic behaviour will be supported by the improvement of facilities, such as hand washing devices, drainage, solid waste collection and deposition, mosquito nets, ventilation, safe food storage, utensil drying racks and safe cooking places. Others helpful factors are linked to environmental measures against dust and mosquitoes, like elimination of ponds and open water, not planting banana trees in front of windows/doors and the removal of waste such as old tires and other material that may store water.

A hygiene/sanitation/habitat check carried out with children, parents and teachers is recommended as the first step in a participatory design process. The aim of the exercise is to identify situations on the school compound that are good and others that would need improvement from an environmental point of view. Once participants have identified their top 5 issues, the facilitator can invite them to suggest a solution, after which others might give alternative suggestions.

The booklet *Smart Hygiene Solutions* provides an excellent review on state of the art technologies and methods for hygiene promotion.

References

Water source options

Water storage options

Water treatment options

Sanitation options



APPENDIX : REFERENCES

Websites:

www.akvo.org (akvopedia/water and sanitation portals/studios and decision support tools)

www.irc.nl (specialized library; downloadable for Smart Solutions series) www.washdoc.info/

www.who.org (Guidelines for drinking water. Many publications on water sanitation and health)

www.unesco.org/education/fresh (former UNESCO school community)

www.washinschools.info (IRC school community)

www.washinschoolsmapping.com

<http://waste-dev.akvo.org/> (sanitation decision support tool)

www.wsp.org/scalinguphandwashing/enablingtechnologies/index.cfm?Page=Browse (on hand washing devices and tippy taps)

www.who.int/water_sanitation_health/hygiene/envsan/phastep/en/index.html (on PHAST methodology)

Literature:

Evaluating household water treatment options

www.who.int/water_sanitation_health/publications/2011/household_water/en/index.html

3IE 2009. International initiative for Impact Evaluation. Synthetic Review 001. Hugh Waddington, Birte Snilstveit, Howard White, and Lorna Fewtrell. 2009. Water, sanitation and hygiene interventions to combat childhood diarrhoea in developing countries. Quoted in: UNICEF 2009. Evidence base: Water, Sanitation and Hygiene interventions; literature review Dec 2009.

Godfrey S., Labhasetwar P., Wate S., Jiminez B.(2010) Safe grey water reuse to augment water supply and to provide sanitation in semi arid areas of rural India; in: IWA Water Science and Technology 2010 pg 1296-130

IRC/Zomerplaag and Mooijman (2005) Child friendly hygiene and sanitation facilities in schools (www.irc.nl)

NWP (2006) Smart water solutions (also at www.irc.nl and akvo.org)

NWP (2007) Smart sanitation solutions (also at www.irc.nl and akvo.org)

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RWSN (2011) Low Cost Handpumps, Field Note 2011-3 (www.rwsn.ch)

UNICEF (2008) UNICEF handbook on water quality

UNICEF/WHO (2009) Water, sanitation and hygiene standards for schools in Low cost settings

WEDC (July 2011) Inclusive design of school latrines-how much does it cost and who benefits (Briefing Note 1; <http://wedc.lboro.ac.uk/knowledge/know.html> (for downloads you need to register (free of charge))

References

Water source options

Water storage options

Water treatment options

Sanitation options



APPENDIX : WATER SOURCE OPTIONS

Below is a series of examples, organized according to water source. If the option is available, the following priority sequence is the most likely, but exceptions are always possible. Except for the second and third solutions (link to existing water points), the solutions are elaborated in separate fact sheets. Lifting devices, tanks and treatment options are dealt with in later sections.

1. **Gravity systems.** Connection to a nearby spring that brings water to the school by gravity through pipes. While investment cost can be high 1.000 - 50.000 US\$, depending on soil type, slopes, yield and distance, the operational costs are very low and quality is mostly very reliable. Protection of the spring area (and feeding area) and seasonal variation are points to consider.
2. Connection to an existing **Piped Water scheme** if it is reliable. Cost is mostly at a very acceptable level (0.2-0.8 US\$/m³), quality is reasonable and operation and maintenance is shared with others. Additional point of use treatment might be necessary.
3. Use of an existing nearby **Public water point**. If this is far from the school the disadvantage is the walking distance with a heavy container, especially for small children, and security may be an issue for small children and girls. A wheeled cart with containers might make it easier to supply a school.
4. **Shallow well with cover.** Disadvantage is the maintenance of pumps and the risk of contamination. Making a shallow well is difficult or impossible where the soil is too rocky or where water levels are deeper than 15 meters. Depending on the type of handpump a shallow hand dug well with a handpump costs € 500 - € 4.000. Maintenance costs are relatively low, but one should allow money for the cost of replacement(s) and any major repairs to both handpumps and concrete superstructure.
5. **Deep well/borehole.** The disadvantages are the high investment cost, risk of failure to find water at or near the school and the maintenance of pumps. Cost of a borehole with a hand or electric pump depend on depth of the aquifer and geology. Drilling through rocks is expensive - in Africa, cost ranges from € 3.000 and € 12.000 – but new drilling methods and low-cost/locally-produced handpumps can be an option in some situations. In the South of Tanzania (Njombe) school water points consist of a manually drilled borehole and a rope pump at 40 m deep at a total cost of € 650 – 800. The Rural Water Supply Network (RWSN) has a good website for guidance on boreholes and handpumps (www.rwsn.ch). Maintenance costs for handpumps are relatively low but one should allow money for replacement(s) and major repairs.
6. **Rainwater harvesting.** This is mostly applied where there is no alternative method or to complement other systems. Apart from roof top harvesting you might also consider run off collection, stream water collection, ponds and reservoirs, sand dams and subsurface dams. Plastic (Poly) tanks are widely available and cost about €100 per m³, excluding transport, concrete support and gutters). Prices of storage options are shown in table 2 (section 2.6). Small dams will cost easily €5,000 – €15,000 and require various additional measures.

Spring Intake and gravity



Spring intake and gravity-fed water main SW Tanzania and SE Kenya (Aqua for All)

Principle Water from a permanently flowing natural spring is captured and brought to the school, mostly by gravity.

Factors Minimum flow of the spring at the end of the dry season. *

Chemical water quality (fluoride, hardness etc)

For gravity, the spring needs to be higher than the school without higher hill tops in between

Design capacity should include 20 years growth of school and might incorporate multiple uses (gardening) and inclusion of community

**A school/community of 500 people using 20 l/day needs 10,000 l/day, or 0.12 litres per second.*

The minimum flow can be determined by measuring the flow 3 times during one dry season and extrapolating the result to the maximum length of dry season.


Elements

- 🔹 covered and protected spring chamber
- 🔹 collection chamber
- 🔹 gravity main (pipe) with wash out valves in lows and air release valves in highs
- 🔹 (raised) storage tank (capacity of half a day flow); remember to include an overflow

Special features

- 🔹 Be aware of 'false natural springs'; re-appearing surface water
- 🔹 Erosion and catchment protection
- 🔹 Deviate upstream drainage water
- 🔹 Break pressure tanks are required when height differences are too high (each 60 meter difference in altitude)
- 🔹 Hydraulic calculation includes friction losses in pipe. Design flow, pipe type and available height difference will determine the required pipe diameter. The hydraulic design should be undertaken by an engineer.

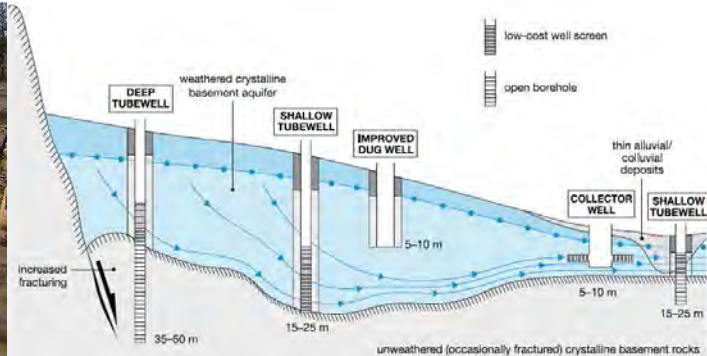


	 Poly pipes (HDPE) are the most economic and flexible, but need to be buried in 60 cm deep trenches. If the pipe is at or above the surface when crossing gullies or hard rock, steel pipes are required.
Optional:	Pump chamber and pump if spring is below school level or if pipe line has to pass a hill top
Treatment	Pre-treatment by screen or strainer (large particles/dirt/frogs). If well made and protected, no additional disinfection or treatment is required.
Main cost element	Pipeline is the most costly element (€2 - €10 per meter, including labour). Tank might be a cost component. Capping of small springs mostly costs less than € 1,500. This method is mostly applied if a small spring is nearby, otherwise to be combined with community supply.
Maintenance	Bi-annual check/cleaning at spring and weekly check of pipeline. Funds for replacements.
Considerations	Ownership of source or user rights have to be arranged. Consider traditional rights. Depletion of spring yields by upstream land use changes and climate change. For hard water, pre-oxidation near the source is recommended (contact with air)
References	www.akvo.org (water portal), www.IRC.nl ,

Groundwater from dug wells



Handpump on shallow dug well



Positioning of dug wells and tube wells (source: Worldbank)

Principle

Shallow underground water is reached by digging a well. The well must be protected by a cover. The lifting device selected must prevent the entrance of dirt into the well.

Factors

There should be a water-bearing layer within less than 15 meter. *

Chemical and biological water quality.

Soil should be good to dig. **

Distance from any sanitation unit, waste dump or other source of contamination at least 50 m.

* in some countries wells are dug much deeper (examples of 70 m)

** in some regions, well diggers can easily dig into hard rock

Elements

- ☑ dug hole with lined walls; usually a filtering ring at depth and closed concrete rings above
- ☑ a closed (and impermeable) cover on top
- ☑ an impermeable (concrete) slab around the well and a drain to prevent re-entry of dirty drainage water and to avoid contamination from unhealthy muddy surroundings
- ☑ a lifting device (see separate section)

Special features

- ☑ digging in hard rock and in fluid sand/silt requires special skills
- ☑ pumps for schools are described in separate section. For shallow water levels, pump types can be cheaper and more maintenance friendly than for deep levels

**Optional:**

Pump to a raised tank (small electric pump (solar) or EMAS handpump). Use a simple but sturdy handpump (soaking or direct action).

Alternative to strong lining is the EMAS 'rooted reservoir well' (see www.akvo.org)

Treatment

Generally, no additional disinfection or treatment is required if there is no chemical contamination, wells are well made and sealed and water is collected in clean containers that are closed afterwards.

Shallow groundwater must be investigated for chemical compounds, like iron, arsenic, salt and nitrates. Turbidity should not be a problem.

Oxidation might be recommended if the water has no oxygen.

Main cost element

Digging and construction is the major cost component and this largely depends on depth, soil type and cost of labour. Costs vary between € 400 and € 4.000.

Maintenance

Regular greasing and maintenance of pump. Daily cleaning of surroundings.

Considerations

Digging is preferably done during seasons with lowest water tables

Best site for a successful well will depend on physical, economic and social factors.

Physical site selection techniques can save time and energy. Examples are manual test drilling and geophysical surveys. The latter can provide information on expected type of soil, depth of layers, salinity of water and sometimes depth of water table.

Significant factor of a dug well is the storage; the significant factor of a drilled well is the yield.

References

www.akvo.org (water portal), www.IRC.nl, is www.rwsn.ch

Groundwater from drilled wells



Baptist drilling (left) light machine drilling (middle) and pumping (right)

Principle Shallow or deep underground water is reached by drilling a well/borehole. The well is protected by a cover. A lifting device is selected that prevents the entrance of dirt into the well.

Factors There should be a good water bearing layer *

Chemical and biological water quality.

Any sanitation unit, waste dump or other source of contamination must be at least 50m. distant

* A drilled well has a much smaller diameter (mostly < 15 cm) than a dug well (mostly 100-150 cm), thus the stored volume in the drilled well is relatively small and the water transporting capacity of the water bearing layer should be much better than with dug wells. Minimum yield is about 750 litres per hour, otherwise the borehole is considered as 'dry'.

Elements

- 🔵 drilled hole with casing and filters at depth; filters are surrounded by a gravel pack; the upper part of the casing is surrounded by a clay seal.
- 🔵 a closed (and impermeable) cover on top
- 🔵 an impermeable (concrete) slab around the well and a drain to prevent re-entry of dirty drainage water
- 🔵 a lifting device (see separate section)

Special features

- 🔵 there are many drilling technologies. Apart from the expensive machine driven technologies, there are several economic manual driven methods (see first column under <http://www.akvo.org/wiki/index.php/Portal:Water>).

Optional: Pump to a raised tank (small electric pump (solar) or handpump).

Treatment Generally, no additional disinfection or treatment is required if there is no chemical problem, wells are well made and sealed and water is collected in clean containers that are closed afterwards.

Shallow groundwater should be investigated for chemical compounds, like



iron, arsenic, salt and nitrates. Turbidity should not be a problem.

Oxidation might be recommended if the water has no oxygen.

Main cost element

Drilling is the major cost component and largely dependent on depth, drilling technology, soil type, cost of labour and remoteness. Costs vary between € 10 and € 150 per meter depth.

Maintenance

Regular greasing and maintenance of pump. Daily cleaning of surroundings. Security.

Considerations

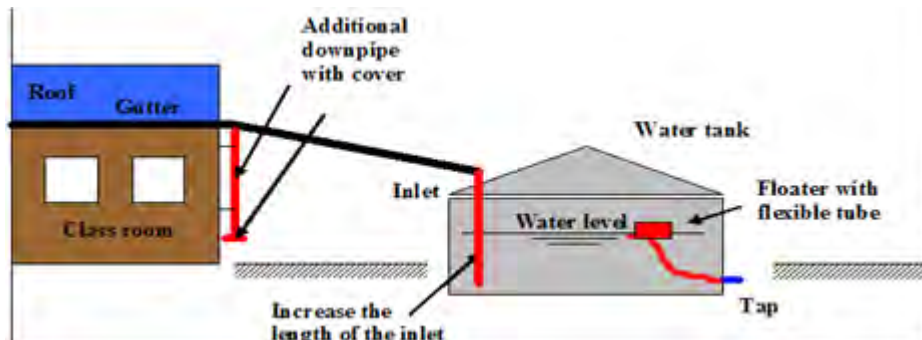
The best site for a successful well will depend on geological, physical, economic and social factors.

Physical site investigation techniques can save time and energy. Geophysical surveys can provide information on expected type of soil, depth of layers, salinity of water and sometimes depth of water table.

References

www.akvo.org (water portal), www.IRC.nl, is www.rwsn.ch

Method Rainwater Harvesting – Rooftop



Principle Rainwater falls on a (hardened) sloping roof. The water is collected in a gutter from which the water flows into a storage tank.

Factors The volume of water that is drained from a roof in litres is the surface area A (m^2) times the rainfall (in mm) times an efficiency factor. The efficiency factor for an iron roof is commonly around 0.75, but much lower if much water is spoiled when it overflows the gutter.

Systems might be over-sized in case they need also to serve the neighbouring community.

If the tank is required to be full at the start of the dry season, the volume (in litres) is the surface area of the roof multiplied by the average rainfall in the wet season (in mm) times the efficiency factor minus the volume of water used during the wet season.

Available water during dry season is calculated as follows. Assuming the tank with volume V (in litres) is full at the start of the dry season, then the daily volume per pupil in litres/day is Volume divided by number of pupils divided by maximum length of dry period (in school days). This should be at least 5 l/pupil per day.

It is a good idea to make these calculations for different drought scenarios.

- Elements**
- 🔹 Inclined roof (clean and hard)
 - 🔹 Gutters with sufficient slope (> 5 cm/meter)
 - 🔹 Screen and first flush (several types)
 - 🔹 Drainage pipes
 - 🔹 Storage Tank (ground tank or underground tank)
- Special features**
- 🔹 Efficiency can be increased with flush board over the gutter
 - 🔹 Keep all openings closed against insects and other animals
 - 🔹 Avoid leakages and remember to have drainage at tap point
 - 🔹 trap the tap water just below the water surface using a floating device
 - 🔹 overflow can be guided into the subsoil for recharge



Optional:	Underground tank is cheaper, but water then needs lifting. Other option: Pump and raised tank (small electric pump or EMAS handpump)
Treatment	Mostly some disinfection (chlorine, silver in tank; or ceramic filter at point of use). Carbon Filter if taste is an issue.
Main cost element	Covered water tank (many options: brick, ferrocement, concrete, Plastic, sub-surface with foil) € 10 – 150 per m ³ storage volume.
Maintenance	Regular cleaning of gutter and first flush; annual cleaning tank; treatment
Considerations	Limited quantity during the dry season; sensitive for extreme dry spells. May be refilled from water tankers. If shared with surrounding community, strict regulations need to be in place.
References	www.akvo.org (water portal), www.rainfoundation.org , www.IRC.nl , www.agromisa.nl ; www.rainwater-toolkit.net

Rainwater Harvesting – Soil/Rock surface



Runoff water collection

Left: using foil (Tunisia);

Right: in Borana, South Ethiopia (Rain Foundation). Mind sand traps and half

Principle Rainwater falls on a (hardened) soil surface. The water is collected in an underground tank, usually after pre-filtration.

Factors $Q = \frac{A * P * E}{N * L_2}$ in litres per pupil per school day

A= Surface area of (hardened) that can be used (in m²)

P= Annual Rainfall (in mm/year)

E= Collection efficiency factor (varying from 0.25 for grass to 0.8 for concrete or tarmac)

N = Number of pupils

L₁= Maximum length of dry season (in days)

L₂= Maximum number of school days during L₁ (in days).

Remember that this is an average; make the similar calculation for extreme years with 70% of mean annual rain fall and the once in 10 years long drought.

Elements

- 💧 (Hardened) protected ground surface
- 💧 Screen and sediment trap
- 💧 Storage Tank (Minimum Volume L₂*N*Q in litres)
- 💧 Treatment and pump

Special features

- 💧 Efficiency can be increased by hardening surface and cutting back vegetation
- 💧 Erosion protection
- 💧 Possibly protected surface
- 💧 Overflow can be used

Optional: Pump and raised tank (small electric pump (solar) or EMAS handpump). Use a simple handpump (soaking or direct action).

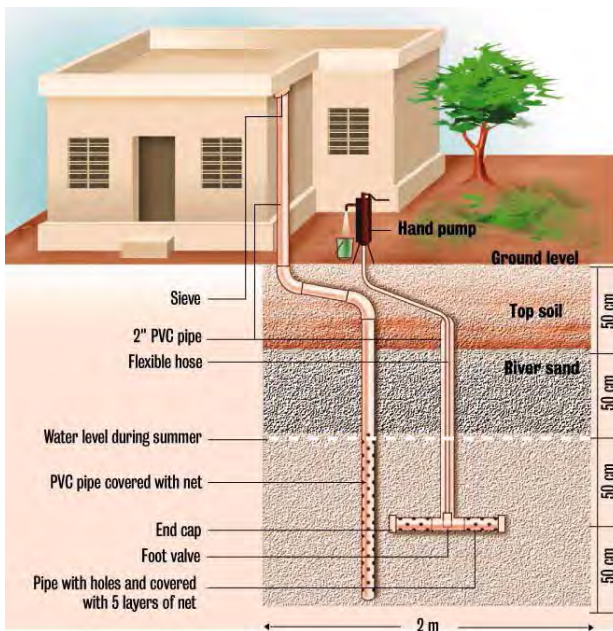


Treatment	<p>Pre-treatment by screen (large particles/dirt) and sediment trap. Sediment trap is large device with <math>< 4\text{ m/hour}</math> water velocity and at least 1 hour retention time.</p> <p>Before pumping, water can be lead through a sand bed between the pump and reservoir.</p> <p>Treatment/disinfection is essential before use</p>
Main cost element	<p>Covered water tank (many options: brick, ferrocement, concrete, Plastic foil, crates); cover can be concrete, sheets, nets, grass.</p> <p>€ 5 – 100 per m^3 storage volume</p>
Maintenance	<p>Regular cleaning of surface area and repair of covers; bi-annual tank cleaning; water treatment</p>
Considerations	<p>Mainly applied when rainfall is too little for roof top water harvesting.</p> <p>Avoid inflow of human and animal excreta</p>
References	<p>www.akvo.org (water portal), www.rainfoundation.org, www.IRC.nl; www.practicalaction.org</p>

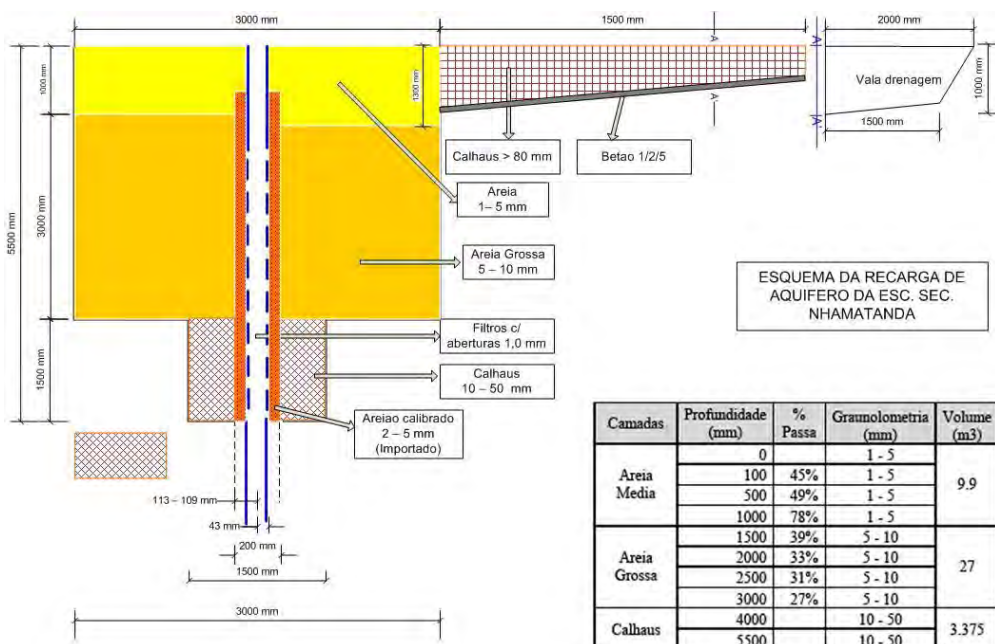
The examples below show alternative ways to harvest rainwater in which the ground itself is used to store the water instead of a tank. There are many geological conditions, where water will not be 'lost', but remain accessible. This underground storage will often have a much larger capacity.

Of course such solutions require higher investment costs.

Example 1: Nhamatanda/Mozambique – rainwater used to infiltrate into the ground from where it is repumped (a) from rooftop and (b) from soil surface (UNICEF 2008).



Example 2: same source as example 1



Stream Water Collection



Left:

Bottom intake (SW Tanzania)

Right:

Rangeni Intake for Hedaru in Tanzania (tzpartners.org)

Principle Water from a permanent stream is collected by an intake or pump and lead into a tank near the school. The water is to be treated. Water can be pumped straight from the river or can be pumped from a pump chamber after pre-sedimentation.

Factors This system is comparable in some ways with the previously described 'spring water collection' and 'runoff water collection'. Water turbidity, flood/damage risks (including the flooding of chambers and pumps), upstream changes and pollution are important factors to consider. Maximum and minimum flows (and water levels) need to be estimated.

Elements

- 🔹 intake structure including pre-screen
- 🔹 deviation structure, bringing the water beyond the flood zone
- 🔹 sediment trap or roughening filter
- 🔹 possible pump chamber and pump house
- 🔹 transport main pipe
- 🔹 storage tank
- 🔹 Treatment and pump

Special features

- 🔹 Point and design of water intake is very important to reduce sediment inflow and to guarantee continuous inflow (stilling basin/reservoir, bottom intake; side intakes). Smart designs can be developed to include small hydropower systems.
- 🔹 A gallery connecting the river to a protected pump well at the river bank might prevent many problems
- 🔹 Sediment trap is large device with less than 4 m/hour water velocity and at least 1 hour retention time. More sophisticated is the roughening filter.

Optional: A pump at the riverbank or on a pontoon can also pump water straight from the river. Beware flooding and risk of crocodiles.

Treatment Pre-treatment by screen (large particles/dirt).



Turbidity reduction required (sediment trap or roughening filter)
Before pumping, water can be lead through a sand bed in between pump and reservoir.

Treatment/disinfection is essential before use
Chemical treatment is rare, but think about any upstream chemical pollution (mining, industry)

Main cost element Intake and treatment structures
If included: pump house

Maintenance Regular cleaning of chambers. Daily operation. Repairs.

Considerations Permits might be required to use surface water.
Generally, this option is too complicated for a school.

References www.akvo.org (water portal), www.rainfoundation.org, www.IRC.nl

Pond Water Collection



Left: suspended intake (USAid)

Right: Spring pond near Arusha Tanzania

Principle Water from a (seasonal) stream or temporary run off is collected in a pond or reservoir, from where it is pumped to a tank near the school. Or water is taken from a well near the pond. The water is to be treated.

Factors This system is comparable in some ways with the previously described 'spring water collection', 'runoff water collection' and stream collection. Water turbidity, flood/damage risks (including the flooding of chambers and pumps), upstream changes and pollution are important factors to consider.
Maximum and minimum flows need to be estimated.

Elements

- 🔹 a pre-sediment trap before the entrance; may also be a reed bed or vetiver grass strip
- 🔹 possibly a dam (earth, stone/masonry)
- 🔹 an overflow/spill way and a hardened dump
- 🔹 possibly a dug out
- 🔹 intake structure for water supply
- 🔹 sedimentation chamber
- 🔹 possible pump chamber and pump house
- 🔹 transport main
- 🔹 tank
- 🔹 Treatment and pump

Special features

- 🔹 Pond or reservoir should be fenced.
- 🔹 Evaporation can be reduced by 'wind breakers' (shrubs, trees) or sheet covers/nets
- 🔹 A gallery connecting the pond to a protected pump well at the river bank might prevent many problems
- 🔹 Sediment trap is large device with less than 4 m/hour water velocity and at least 1 hour retention time. More sophisticated is the roughening filter.

Optional:

Treatment Pre-treatment by screen (large particles/dirt).
Turbidity reduction required (sediment trap or roughening filter)



Before pumping, water can be lead through a sand bed in between pump and reservoir.

Treatment/disinfection is essential before use

Chemical treatment is rare, but mind upstream chemical pollution (mining, industry)

Main cost element

Intake and treatment structures
If included: pump house

Maintenance

Emptying of sediments in pond/reservoir. Regular cleaning of chambers.
Daily operation.

Considerations

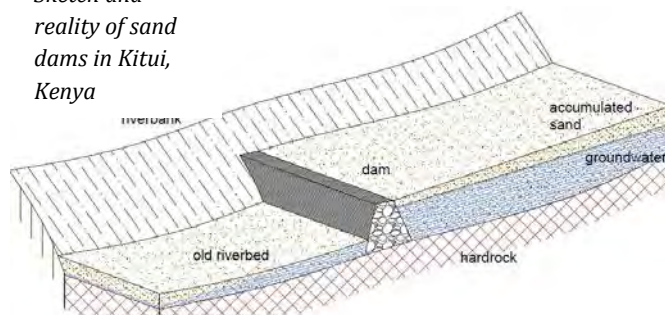
Permanent standing water is a health risk. Ponds should be at some distance from schools. Fish might be used to fight mosquitoes.
Permits might be required to use surface water.
Generally, this option is too complicated for a school.

References

www.akvo.org (water portal), www.rainfoundation.org, www.IRC.nl

Sand Storage dams

Sketch and reality of sand dams in Kitui, Kenya



Principle

A low dam is placed in a streambed with intermittent flow. When there is storm water, a sand body is created behind the dam. This sand body will keep back groundwater.

Factors

This technology is only applicable in stream valleys with an impermeable base, a gradient of more than 3% and sufficient sand transport from upstream.

Elements

- 🔹 a dam (mostly stone masonry), well anchored into the valley sides
- 🔹 a well connected to the main sand body (may be through a connecting drain)

Special features

- 🔹 Part of the sand bottom needs to be fenced to avoid direct contamination of the shallow ground water.
- 🔹 In areas with less sand, the sand body might be developed by raising the wall by half a metre every year.

Optional:

Instead of a well, the water could also be tapped (by gravity) through a drain, leading to a lower tank with an automatic floating ball valve

Treatment

If well constructed and well protected, there is hardly any need for treatment. Disinfection might be recommended, because of risk of short circuit in the sand body.

Main cost element

Dam (between € 5.000 and € 15.000). Dam can be for a school alone, or shared with the community.

Maintenance

Emptying of sediments in pond/reservoir. Regular cleaning of chambers. Daily operation.



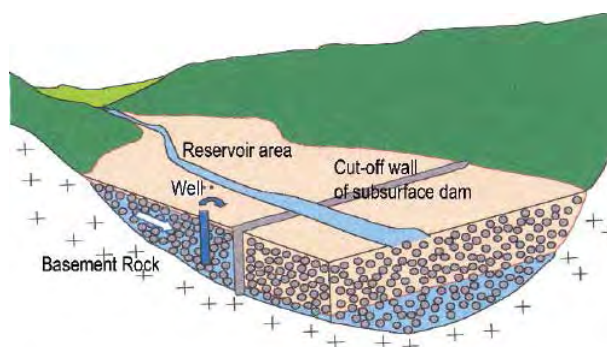
Considerations

Maximum floods/stages are important to consider. Erosion is a risk at the side walls and at the spilling floor.

References

www.akvo.org (water portal), www.rainfoundation.org, www.IRC.nl; bebuffered.nl; www.waterforaridland.com

Subsurface dams and galleries



Sub-surface dams (from Belgina publication on Turkana case; www.bebuffered.com

Principle A blocking wall is constructed in the riverbed. The water in the riverbed will remain and is available for use.

Factors This technology is only applicable in stream valleys with an impermeable base and a sandy riverbed. The riverbed should not be too wide and rather stable.

Elements

- ☑ a wall (mostly stone masonry, but can also be compacted earth/clay or plastic sheets),
- ☑ a well connected to the main sand body (may be through a connecting drain/gallery of filter pipe or even concrete)

Special features

- ☑ Part of the sand bottom needs to be fenced to avoid direct contamination of the shallow ground water.
- ☑ In areas with less sand, the sand body might be developed by raising the wall by half a metre every year.

Optional: If there is sufficient gradient, the water can also be drained through a tube to a downstream tank with an automatic floating ball valve. If the riverbed has permanent water, the subsurface dam may not be required and a gallery could suffice.

Treatment If well constructed and well protected, there is hardly any need for treatment. Disinfection might be recommended, because of risk of short circuit in the sand body.

Main cost element Dam/wall. Depending depth of impermeable base and width of riverbed.

Maintenance Water collection device. Flood damage



Considerations

Maximum floods/stages are important to consider. Erosion is a risk at the side walls and at the spilling floor.

References

www.akvo.org (water portal), www.rainfoundation.org, www.IRC.nl; bebuffered.com; www.waterforaridland.com; Erik Nissen-Petersen

References

Water source options

Water storage options

Water treatment options

Sanitation options



APPENDIX : WATER STORAGE OPTIONS

Water storage can serve different purposes:

1. to create a buffer between the supply and peaks in demand, whether on a daily or seasonal basis
2. to create rest periods during the day or night for a pump or the caretaker
3. to create (constant) pressure in taps if tanks are raised
4. to allow treatment such as the settlement of suspended particles

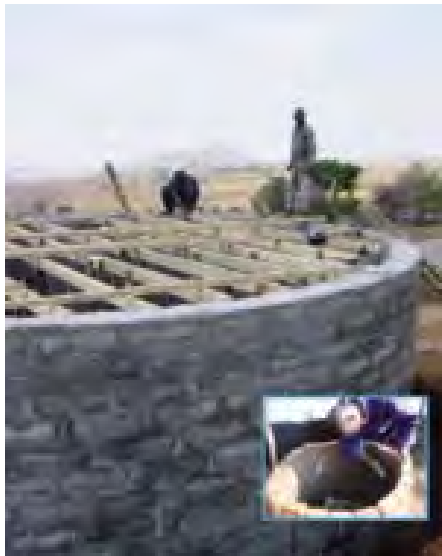
There are many different tank types, from the traditional masonry and concrete ones to the cheaper ferrocement, or ones, which are made with, wire, cement local materials like bamboo, bricks or clay. These options are more economic than the traditional concrete tanks but all need skilled labour to construct. Another option is a plastic tank of 500 to 5,000 litres, but these are still rather expensive and need protection against sunlight. A recent development is strong plastic bags known as foldable, flexible or collapsible tanks, which are now used in Uganda. Other 'cheaper' solutions are prefabricated tanks of metal sheets, lined with plastic. These tanks can be of a very large volume and can be roofed.

It is recommended that water tanks have a wash out (to ease regular cleaning and to flush the sediments) and a regulated overflow (in case the inflow is too high) thus tanks should be equipped with entrance and outlet valves. A good quality automatic floating valve, which closes when the tank is full, is recommended, but will be costly. Openings such as vent pipe, overflows and others should be protected against insects and animals with mosquito wire. If tank-stored water is to be used for drinking it is recommended that there should be some treatment at the outlet or a Point of Use treatment option like disinfection or filtering.

A well-sealed and durable roof is the most complicated part of the tank. Experience in Kenya of roofing large volume tanks (>50 m³) has demonstrated the importance of a central column, well designed positioning of any iron bars and the importance of wet curing.

The following examples of tanks are mainly taken from www.Akvo.org

Brick tanks and wire cement tanks



Brick cement tanks are a low cost option for storing water gained through water harvesting. They are generally cheaper than ferrocement tanks, are easier to build and can be 0.5 to 30 m³ in volume. The area should be suitable for **rainwater harvesting**. Brick cement tanks are constructed by placing an upright ring of bricks in a circle, with 3 rings of steel wire tightened around them. If the tank diameter is bigger than 2 meters more rings are needed. A second, third and fourth ring of bricks are added and suitably tightened. Cement is then applied on the inside and outside of the brick walls and to cover the bottom. A metal or PVC outlet pipe can be installed at the bottom. Once the cement has been applied, the tank needs to be covered with paper or plastic and kept wet for 7 days to cure the cement. Another curing option is to fill it up after the second day of installation.

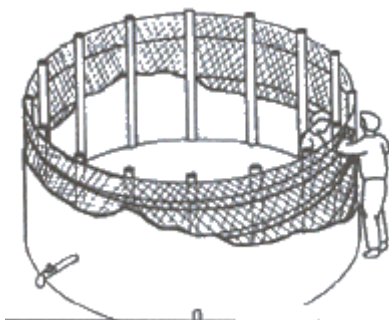
Materials consist of (locally produced) bricks (or blocks of hard rock), cement and steel wire. Approximately 1 bag of 50 kg cement per m³ tank volume. The bigger the volume of the tank, the lower the amount of materials (and thus costs) per m³ tank volume.

Bricks are used to make smaller tanks of 0.5-3 m³ and natural stones or cement bricks are used for tanks of 3 to 120 m³. Leaks are repaired with cement.

(www.akvo.org)

Cost indication: € 10-20 per m³

Ferrocement tank



A ferrocement tank consists of a core of chicken weir/small diameter mesh along poles, which is plastered at two sides with concrete mortar. They are also referred to as 'wire reinforced mortar tanks'.

Use of 1.3 – 1.5 cement bag per m³ storage. Minimum mortar cover over the mesh is 2 mm, but application goes often up to 20 mm. Typical sizes are 2 – 30 m³

Long and wet curing is a critical factor.

Cost indication: € 20 – 40 per m³

Traditional concrete tanks



Concrete tanks use iron bars in foundation, walls and roof. The roof can be flat or inclined and needs a vent pipe. Wider tanks need a support pillar in the centre.

Most countries have remained with the standard designs developed during colonial times. They are commonly more expensive than alternative designs.

For larger diameter sizes, a central column is recommended. Reinforcement of the roof requires technical expertise.

Cost indication: € 50 – 120 per m³

Poly tanks



The advantage of poly tanks is that they are prefab and need little additional construction work. They need to have a stable basis and preferably they are covered with a roof (galvanized sheets or thatched with grass) and you must try to close all openings.. They can be put in series. Lifetime is less than 10 years and is heavenly dependent on exposure to sun rays. There exist conical models in which the separate roof/cover provides some strength. The advantage is that their transport is cheaper (as they fit together).

Poly tanks require a flat and stable (concrete) stand and are often placed on a raised column (of concrete or iron). Roofing against UV-rays is recommended. Make sure that sufficient space is available between bib-cock and ground and that drainage is assured to avoid muddy places at the collection point.

In some countries, there are sub-surface tanks, consisting of two halves that are put together.

Cost indication: € 70 – 130 per m³

Welded sheet tanks (example Bucon)

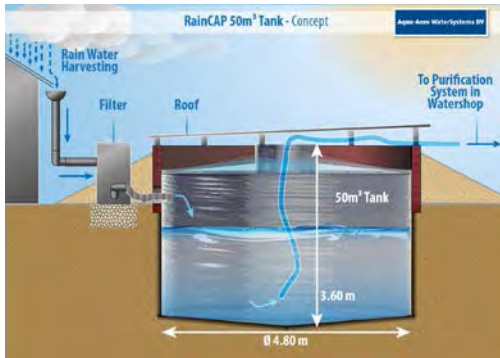


The outer part of these prefab tanks consist of iron sheets, that are put together with bolts and nuts. The inner side consists of a plastic lining with openings for the wash out and outlet pipes. Also the roof is from prefab sheets. The base needs to be stable.

This type is common at industrial plants and in agriculture. Advantage is the prefab and limited volume, reducing transport costs. Disadvantages are the price of the plastic foil, the costs of additional items and the required care in cleaning and maintenance.

Cost indication: € 90 – 150 per m³ (ex factory; including accessories)

Foil lined subsurface tanks (example of RainCap of Aqua Aero Systems)



The Rain Collection And Purification system (RainCAP) is a foil sheet, put into a dug out or in an existing tank. The sheet is made of a very sturdy and durable plastic. The foil tank is placed in the ground and used to collect/capture up to 50 m³ of rainwater. From there the water is pumped up, purified when needed and distributed as drinking water to the consumers.

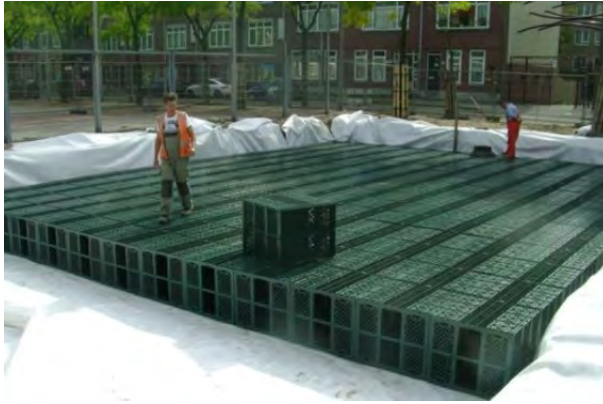
The RainCap system is easy to transport, install and maintain. It can be installed in combination with the UV WaterBox. The tank can be cleaned regularly and removed when needed.

www.aaws.nl/images/stories/bestanden_aaws/brochure_rainCAP_mail.pdf

Cost indication: not yet fully at scale



Crates based subsurface tanks (example of Wavin)



The modular crates, surrounded by strong foil, are meant to provide a solid subsurface below an area that can be used for a second purpose. The water tank can be used to store the water or to create a buffer for slower infiltration into the ground.

Care should be taken to keep all openings closed. The water entrance can be kept closed with a siphon/water guard.

http://overseas.wavin.com/master/master.jsp?products=products&middleTemplateName=oc_middle_system_detail_I&FOLDER%3C%3Efolder_id=2534374305497647&c=products&p=/Assortments/017/017/External_017_Products/Storm_Water_Management/WavinAquacell

Cost indication: not yet fully developed for most developing countries

References

Water source options

Water storage options

Water treatment options

Sanitation options



APPENDIX : WATER TREATMENT OPTIONS

Water treatment is required for all surface waters and sometimes for groundwater, spring water or rainwater. As mentioned, water may become recontaminated during transport and storage, which is the reason why treatment is needed to avoid regrowth of micro-organisms. One cause of recontamination in pipes can be where the distribution is done by rotation (one may get water during a few hours per day only): when there is no (or low) water pressure contaminated groundwater may enter into the pipes. Usually chlorine is applied (4 mg of free chlorine per litre) to avoid regrowth of algae and bacteria, but a newer and less well-known option is colloidal silver, which is less problematic for health (see below), but more difficult to monitor for as a residue than is chlorine.

Centralized treatment can be done by the Water Company/ supplier or there are decentralized treatment options through plants like Perfector, Water maker Naiade etc. These systems have capacities of 500 to 50.000 litres per day and need very regular operation and maintenance with more or less skilled technicians.

Turbid water needs to be pre-treated to remove the suspended particles. This can be done with 'filters' or by adding flocculants like Aluminium Sulphate/Alum, Moringa seed powder or other local products. Water that has *no oxygen* needs to be oxidized (mostly by letting it fall through the air). This may also remove excessive iron and manganese.

Disinfection technologies can be divided into:

1. **Ceramic Filters**, Examples are ceramic filter of the Pot, candle or Siphon model. Other options use membrane technology like the Perfector in large systems and Life straw family in small systems at household scale,
2. **Sand filters** combine the physical filtering of sieved sand with the biological treatment of the bio-film at the surface. Biosand filters are applied for small scale and slow sand filters for larger scale. Rapid sand filters are not meant for disinfection.
3. Other physical removal is done by **boiling** or by the application of **UV-light** (lamp or sun rays). Both are very effective in eliminating bacteria and viruses but boiling has disadvantages like cost of fuel, indoor pollution, time required to prepare, carbon emission etc
4. **Chemical Disinfectants**, The most common used disinfectant is chlorine, which is used in piped and centralized treatment systems. At the household level chlorine options come as a liquid (Waterguard, Certeza) or as tablets (Aquatabs). Chlorine can be locally made by the electrolysis of salty water (e.g. by using the WATA). There are several chlorine products which do not affect the taste and are healthier (NaDCC-tablets/Aquatabs, Twinoxide). Another disinfectant is silver, which can eliminate all harmful bacteria but is not toxic by comparison to chlorine, does not have a smell or taste and has a long shelf life. Silver may be applied in liquid form like Silverdyne or as a floating ceramic sphere like Plation. The presence of residual silver is more difficult and expensive to measure, compared to chlorine but several companies are further developing this promising option.



5. Products that use **combinations** of the above mentioned technologies such as the Pureit filter.

Information about a wide sample of water treatment products is provided on the next page and their evaluation in appropriateness, performance and price (cost per m³ over the life cycle) is provided in table 3.

Filters like Life straw family and Pureit eliminate turbidity and practically all bacteria and viruses. Other filters like the Berkefeld, Brita, Swach and Tulip eliminate turbidity and up to 99.99% of all harmful bacteria. Ceramic pot filters eliminate turbidity and reduce bacteria by 90 -99% and biosand filters reduce turbidity and bacteria with 50-98%. New generation filters like the Tulip or Life straw family model have high filter speeds of 80 to 150 litres per day and could be used in schools. One filter would be enough for 15 to 30 children. Cost of these high capacity filters range from €9 -€30 with a filter capacity of 5.000 to 15.000 litre. As with other technologies, training in maintenance is essential. When evaluating the different options, one should also evaluate the readiness of people to use the method for a longer period.

The selection of treatment technologies for schools is dependent on a number of factors:

- 🏠 type of water source, its water quality and the variability of turbidity
- 🏠 the need for pre-treatment to reduce turbidity for more effective treatment
- 🏠 the need for reduction of specific chemical compounds (e.g. iron, arsenic, fluoride, nitrate)
- 🏠 the need for reduction of biological contamination (bacteria, viruses, helminthes)
- 🏠 the choice for a centralized or decentralized treatment
- 🏠 financial, technical and cultural factors

For financial reasons, it may be necessary to separate ordinary non-potable water from taps and specially treated water for drinking. This requires good education and sufficient warning information at any water points with non-potable water.

Taste can be improved by the use of activated carbon. Filter brands that use this are for instance Korean king, Berkefeld, Stefani, Brita and Tulip.

Some *inorganic chemical elements* can be easily removed, but most of them need sophisticated devices and hence skilled staff. Special care should be taken with Arsenic, Fluoride and Nitrates.

For more information about disinfection see Smart Disinfection Solutions

Remember, much can be done by *prevention*. This can be done by ensuring the full coverage of spring box or well heads and the avoidance of entry of drainage water into the water source. For rainwater a sieve and a first flush device are needed before the water enters the storage tank. Tap water should be collected in safe jars, jerry cans or other containers that can be closed.

Slow sand filter (example Jal-TARA)



The slow sand filter ensures a simultaneous bacteriological and physical improvement in water quality comparable to the natural percolation of water through underground strata. Jal-TARA is standardized in 1000 litres water tank with the output water supply of 2500 – 3000 litres per day. The filters contain pebbles and sand of different sizes. The system is provided with a synthetic fabric filter designed with advanced technique of fabric protection. The system can be fed under gravity flow or through conventional pumps or powered by photo-voltaic solar energy.

Operation

The top 5 to 10 cm of wet sand must always be under oxygen rich water. Therefore, the system needs continuous water flow. Large and fine particles of suspended matter are deposited on the surface of the filter bed by the action of mechanical straining and sedimentation, respectively. The colloidal and dissolved impurities are removed by adsorption, whilst the organic matter is converted into organic salts by the purification mechanics. The filtered water is collected at the bottom via a pipe system. Most microbiological action takes place in the 'Schmutzdecke' (bio film) formed in the fabric filter at the top of the sand bed.

Maintenance

The system is designed to have very little maintenance. The filter does require regular cleaning, though the frequency depends on input water quality (turbidity and bacterial contamination) and filtration rate. Cleaning operation includes cleaning of fabric filter and top sand layer. Fabric filter requires cleaning twice in a year for turbidity 10 – 15 NTU input water. To simplify cleaning operation, backwashing facility is also provided.

Manufacturing

Filter can be easily assembled from locally available material like sand, pebbles and water tank. However, fitting material can be easily transported, if not available locally.

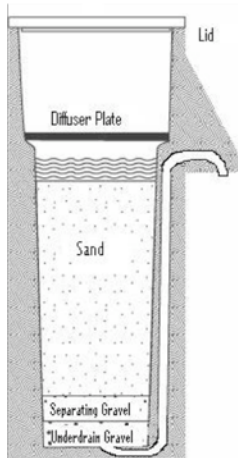
Considerations

Although the technology seems to be simple, many slow sand filters fail by inadequate operation and maintenance.

Cost (for treatment and storage only)

Investment for Jal-TARA example is € 1.300. Unit price per m³ is about € 0.22.

Bio-sand filter (example CAWST)



The biosand filter (BSF) is an adaptation of the traditional slow sand filter, which has been used for community water treatment for hundreds of years. The BSF is smaller and adapted for intermittent use, making it suitable for households.

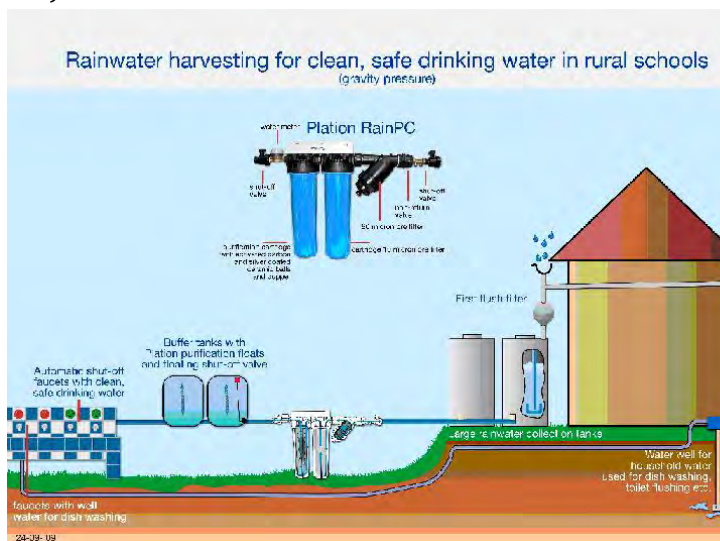
Water treatment is carried out by the sand inside the filter. The filter container can be made of concrete, plastic or any other water-proof, rust-proof and non-toxic material, though concrete has several advantages.

Pathogens and suspended material are removed from the water through a combination of biological and physical processes. These occur both in the bio layer and within the sand bed. These processes include: mechanical trapping, adsorption/attraction, predation and natural death. It is not required that the bio-film remains under water, all the time.

Cost (treatment only)

Investment costs depend on the material applied. Prefab will cost between € 100 and € 200; but they can also be made from local materials or be locally manufactured. Sand and gravel can be re-used after cleaning. Estimated unit price is € 0.11 per m³ treated.

Micro-filters in combination with other absorption filters (example Rain PC; Aqua Est)



AquaEst offers a wide range of water purification products which are applicable in various situations. In the Rain PC system, **rainwater** is purified by means of multi-stage and multi-media filtration. It's a three-stage filtration system using 80 micron and 10 micron pre-filters along with an activated carbon filter in which the colloidal silver-ceramic balls and metallic copper are embedded. The RainPC eliminates (pathogenic) bacteria and organic and inorganic pollutants/contaminants.

Operation

Operation of the Rain PC is very easy. It can be operated at low gravity pressure, as well as pump pressure up to 6 bar (in case of underground storage). The water flow is maximum 8 litres/minute, though this depends on the level of pollution.

Maintenance

Practically no maintenance is required. For the Rain PC system, the 80 micron filter has to be inspected and cleaned regularly. The 10 micron prefilter and filter cartridge with activated carbon, silver ceramic balls and metallic copper have, in adequate systems, a capacity of up to 150.000 litres without further maintenance.

Manufacturing

There is no possibility for local production of the purifying/conserving equipment. However other rain harvesting tools, such as gutters, taps or tanks can be produced locally.

Estimated Lifespan

The entire system has a service life of at least 15 years. The cartridges and 10 micron pre-filter can process a maximum of 150 000 litres, though the lifespan depends on the extent of pollution.

Cost (treatment and taps)

Investment costs about € 1.000 and relatively high replacement costs. The shown unit costs about € 2 per m³all in.

UV-filter (example Naiade, Clean Water Now)



The Naiade water disinfection unit is a spin-off from Nedap's and Trojan's know-how of large scale drinking water and industrial waste water treatment plants. The Naiade drinking water disinfection unit very effectively combines the potential offered by solar energy, UV light and battery back-up.

The Naiade has been designed to remove bacteria, protozoa, viruses and colloidal parts from raw fresh water. It operates without the use of fossil fuel or chemicals, but uses a battery.

The unit is made of tropical resistant poly ethylene. Its dimensions are 150 x 50 x 50 cm. The purification of the Naiade includes:

1. a sieve to remove larger parts such as leaves, stones etc.
2. a 25 micron filter bag
3. a 10 micron filter bag
4. a UV light, which kills any remaining bacteria and viruses

The Naiade has a LED warning indicator, informing about UV-lamp lifetime..

The normal flow rate is 5 – 6 litres per minute.

Operation

The Naiade can be installed in 30 minutes by local people without a technical background. A step-by step, pictured instruction leaflet and tools are provided. The unit is so easy to use that even small children can operate it.

After having filled the unit with raw water, one just pushes the button. Clean and disinfected water flows out from the tap. No waiting time is required. Water flow can be stopped/interrupted by pressing the button again. After 2 minutes, the tap closes automatically to avoid spillage of water. The flow rate is not influenced by the user, it is restricted by the design to guarantee a proper UV treatment of all passing water.

The capacity is about 3,500 litres per day, depending on the scale of organization.

The unit can function at night using a car battery of not less than 37 amp/hr capacity.

A supervision structure to guarantee optimal use is highly recommended.



Maintenance

Both filter bags can be removed from the unit for cleaning purposes. After careful flushing these bags can be replaced. The life span of the UV lamp is 10,000 operating hours, nearly 3 years. The UV lamp can be replaced within half an hour by the users themselves.

The cleaning procedure should be as follows:

- 🏠 Daily cleaning the PV panel for optimal energy supply
- 🏠 Regular rinsing or washing of the filter bags to avoid blockage by sediments or a micro biological layer
- 🏠 Regular cleaning of the glass tube of the UV lamp to avoid sedimentation. This highly depends on the chemical consistency/content of the raw water.

The UV lamp is a standard industrial UV lamp.

Manufacturing

The unit does not contain any moving parts except for the electro-magnetic tap.

It is made of tropical resistant poly ethylene. All material as well as the applied technology is based on the intensive use in remote and tropical areas.

Estimated Lifespan

The estimated lifespan of the unit is over 10 years. Filter bags and UV lamps may need earlier replacement. The UV lamp has a life of 10.000hrs or 3 years at 9 h/day continuous service. The filter needs to be replaced approximately every 12 months depending on TSS of influent/washing frequency. The backup battery (12V-50Ah) lasts 36 hours. Built-in electronics will register the used time of lamp and a light in front of the unit will indicate when the lamp needs to be replaced.

Cost (treatment including storage)

The ex-factory costs are € 3.000 (excluding training). Unit costs are about € 0.59 per m³.

UV-light and other treatment (example Water Box, Aqua Aero systems)



Highly reliable and state of the art UV technology is used, power by solar panels and a battery. The radiation of a UV lamp is transmitted into the water and as result all bacteria, viruses and other pathogens are killed. The effectiveness of our UV system is 99.9 % dependant on the quality of the water intake. Systems are delivered in combination with proper filter techniques so that the sediment content is reduced and taste and odours are removed. Pre-filters for different chemical compounds can be added.

Dependant on the application 5.000 -20.000 litres (or multiple) of water volume are purified on a daily basis.

Cost (treatment only). The investment cost will depend on the housing of the UV-unit. The water box is about € 1.500. Unit cost (without storage) will be about € 0.30.

Chlorination through electrolysis (example WaterPurifier, Bright Spark)



The WaterPurifier is a water treatment system that can be installed in rural areas. The unit removes all pathogens and produces clean and safe drinking water without external use of electricity or chemicals.

The contaminated water is first filtrated with a ceramic filter, then a second time using a disinfection unit using electrolysis, which is solar powered. The applied membrane is a 1 m² tubular ceramic ultra filtration membrane with a pore size of 40 nm. The ceramic membrane has 120 tubular membranes inside with inside diameter of 2 mm.

The WaterPurifier is different from other water purification systems, because it only needs sunlight to operate and the unit creates disinfectant from the salt in the water that provides residual chlorine, thus preventing recontamination. It can be used everywhere. It is extremely robust, compact, and easy to transport.

Operation

The WaterPurifier is very easy to operate. One main switch will switch the unit in operation ready mode. If you tap the purified water the disinfection will start immediately. If you stop



tapping water the disinfection is switched off. To generate enough pressure for the filtration process, water has to be kept in the barrel above the unit. Water pressure results in clean water. If the water barrel is empty a LED alarm light will warn you.

It is also possible to add kitchen salt (NaCl) if there the fresh water does not contain sufficient Cl⁻ for disinfection. About 50 gram per 1000 litres is recommended. For a production of 150 m³ water per year, this will cost 7.5 kg salt. The WaterPurifier can be scaled up to 5 times in the same configuration. In that case 3 to 6 m³ water/day can be treated.

The WaterPurifier is a self-contained, ready-to-use water purification unit. There are no moving parts within the flight case as everything is build on a frame that does not move. The flight case is build so that it can be dropped on a luggage belt; normally the cases will be pitched on this. So it can survive in a lot of circumstances.

Quality can be checked with an indicator strip. If no free chlorine is present, the quality might be poor.

Maintenance

Maintenance is simple. The filter is cleaned with a hand-powered air pump or a bicycle pump which can pump up a small air container up to 6 bar pressure. This handmade pressure is used for backwashing the membrane filter with an air pulse driven clean water backwash.

Manufacturing

The membrane and electrolysis cell cannot be manufactured locally, as they are unique parts of Bright Spark. However, other parts can be locally produced.

It has a flexible raw water tank capacity of 300 or 600 L/day (10-hour operation) with connections. Accessories including are: handpump 15 l/m in bucket, 220 Volt AC to 12 Volt DC adaptor; 12 Volt DC solar panel 15 pW (standard level), 12 Volt DC solar panel 150 pW (high level), oil drum 220 litres, mounting set for connecting tube/hose to a second hand oil drum, 2 m hose with GEKA connectors, tube connectors GEKA, clean water can (20 or 60 litres), water quality indicator sticks (365 units), stand for raw water tank (wood), and stand for raw water tank (aluminium).

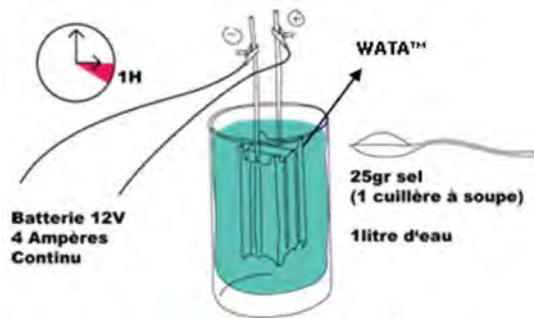
Estimated Lifespan

The estimated lifespan is 20 years if well maintained. The membranes and the electrodes have to be replaced after 5 years.

Cost

The investment cost of the WaterPurifier is € 1.800. Unit price is about € 1.21 per m³.

Adding chemical disinfectant (example mini-WATA for chlorine)



The WATAsol is a simple device which produces active chlorine from salt water using electrolysis. The device consists of two tungsten electrodes in a plastic container, and a transformer. The active chlorine forms hydrochloric acid when added to water. As the active chlorine has a very strong oxidizing power, it destroys almost all pathogenic germs. The WATA device and its use was designed by [Antenna Technologies](#) based on the norms of the World Health organization on for example the accepted quality of water, amount of chlorine needed to disinfect 1L of water and the acceptable amount of free residual chlorine.

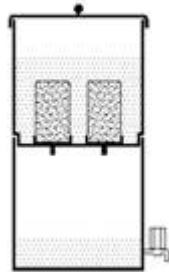
The mini-WATA is a variation of the WATAsol that fits into a regular water bottle. It produces active chlorine to treat up to 4800 litres of water per day, which is enough clean water for the daily needs of 240 people. It can run on 5V/1A but requires a minimum of 10W.

Cost

The smallest sized WATA-mini costs € 40, the standard one € 200 and the maxi € 1.700. The unit costs are around 1 or 2 cents only.

Instead of school wide solutions, one can also use units at the level of a class or a canteen. These might include products that are fit for households. Of the ones with a bit higher production, the following examples could be your choice.

Table top with candle filter (example Water4Life)



Water4Life makes use of the so-called gravity purifier with ceramic filter candles, the heart of the system.

Water4Life cooperates with two different manufacturers of filter candles. Both can achieve filtration of bacteria from the water to a level of more than 99%. Both models consist of porous ceramics with silver impregnation to prevent regrowth of pathogens. This combination assures a high reliability of the filtration of bacteria. One type of candle also contains granular activated carbon, which can absorb some chemical and mineral contaminants, leading to some improvement in taste. However, this is of secondary interest.

Cost

The Water for Life filter costs about € 16 if locally assembled. Unit price is about € 0.42 per m³.

Table top with candle filter (example Tulip)



The Tulip Table Top water filter is a fast flow candle-type water filter, which uses gravity pressure to force water through a high-quality ceramic filter element filled with activated carbon. An innovative patent pending device makes it possible to double the average flow.

The filter element is impregnated with silver in order to increase the bacterial removal efficiency and to reduce the recontamination risk of stored filtered water.

The transparent housing enables frequent refilling without the risk of water overflow from the storage container.

Refilling once per hour, the unit delivers 3 litres per hour, without refilling an average flow of 2.5 litres per hour is realized.

The filter is also available through NAZAVA.

<http://www.nazava.com/english/>

Cleaning of the filter

The filter element is covered by a washable pre-filter in order to protect the filter element against premature clogging when using dirty water. After some time, the flow rate will reduce because of clogging of the filter element. The filter element can be cleaned with a cloth or toothbrush. When this cleaning does not result in a sufficient flow, a small layer of the ceramic material of the filter element has to be removed by scrubbing the filter with a scrub pad, which is included.

Cost

The price of the tabletop model is around € 10- 15, depending the possible use of local buckets. The ceramic filter is to be imported from India.

Silver disinfectant (example Plation Float of Aqua Est)



All Plation® products are based on de-activation of (pathogenic) bacteria by silver ions. The use of silver as a water purification technique goes back millennia and is a proven method. The silver ions are released by a natural ionization process using special ceramic balls with a coating of pure, high quality colloidal silver (microscopic small silver particles). For heavily contaminated drinking water as well as rooftop harvested rainwater, silver-ceramic balls are combined with metallic copper, as copper and silver ions together are even more effective against bacteria, algae and other microbiological contamination.

AquaEst offers a wide range of products.

Plation floats are primarily designed for preservation of drinking water in tanks and cisterns. Product range can suit tank sizes from 50 up to 6.000 litres.

Plation PM is encased in rigid plastic tube. Plation PNS, PNK and JC are kept secured with open mesh food plastic. Plation floats are the only known non chemical, non toxic technique to preserve (drinking) water during storage to ensure fresh and safe drinking water quality. The Floats can also be used for purification/disinfection, either alone (with a proper exposure time) or complementary to other technologies such as activated carbon, UV and RO.

Price

The price of the Plation floats is relatively high.

A new device for sustainable application in water tanks for a 1 year operation is foreseen to enter the market in 2013. This would be fit for the purpose of school tanks. Below € 0.11 per m³ treated.



Physical filtering: clock wise from top left: Tulip, Ceramic Pot Filter, Water for Life candle filter, slowsand filter, Kanchan filter and biosand filter

Physical inactivation: clock wise from top left: Aquapack (solar heat+UV), SODIS, Naiade (solar driven UV-lamp) and boiling



Chemical disinfection: clockwise from top left: AquaEst Platon (silver), AquaEst Rain (membranes, silver, coal), Aquatabs, WATASOL, chlorine and PUR (floc + chlorine)



Multi-process: clockwise from top left: Lifestraw Family, Pureit, Perfector, WaterPurifier

Sample of small scale disinfection products

Best/Cheap Buy	Product process, removal agent	Product name, brand	Capacity ltr/day	Unit price (in €) €/m ³	Overall AT-score *	Sub-score Performance	
						Sub-score Planet/People	
Limited virus and bacteria reduction							
	Plation floats (ceramic silver balls)**	<i>AquaEst</i>	(50)	0.75	6.6	6.1	7.0
	Biosand filter	<i>CAWST; Hydraid</i>	100	0.11	6.4	5.7	8.0
	Arsenic reducing biofilter	<i>Kanchan, ENPHO</i>	50-75	0.11	6.1	5.3	7.0
Limited virus reduction							
BB	Ceramic Silver Pot Filter	<i>Potters for Peace</i>	15-30	0.57	7.9	7.9	8.0
CB	Ceramic/carbon candle	<i>Water4Life</i>	25-50	0.42	6.3	5.7	5.5
CB	Siphon ceramic silver filter	<i>Tulip, Basic Water Needs</i>	50-80	0.51	6.1	6.1	5.5
	Plation Rain Purification Centre	<i>AquaEst RainPC</i>	275	2.00	5.4	5.7	5.0
	Slow Sand Filter	<i>e.g. Jal-TARA</i>	(2.750)	0.22	5.2	4.4	7.0
Good virus reduction, individual-family size							
BB	Chlorine drops, hypochlorite	<i>e.g. Safe Water Storage</i>	NA	0.24	7.0	8.3	4.6
	Solar UV - PET bottles	<i>SODIS</i>	1-mrt	0.87	7.0	7.0	6.5
	Boiling (electrical; wood)		NA	17.85	6.8	7.9	4.0
	Sodium dichloroisocyanurate tablets **	<i>NADCC aquatabs</i>	NA	3.25	6.5	7.9	4.6
	Sachets flocculant/disinfectant	<i>PUR, Procter&Gamble</i>	NA	7.14	6.5	7.9	4.6
	Solar UV/IR heat, plastic bag	<i>Aquapak</i>	5	3.13	6.4	6.1	6.0
	Iodine & micro-filter in suction 'straw'	<i>Lifestraw, Vestergaard</i>	1 (max 10)	4.08	6.4	6.1	6.3
	Iodine & ultrafilter, gravity	<i>Lifestraw, Vestergaard</i>	15 (max 150)	0.79	5.3	4.9	5.2
	Carbon, filter, chlorine	<i>Pureit, Unilever</i>	20	4.35	5.1	5.3	5.0
Good virus reduction, group size							
CB	Multi-filter and UV	<i>Perfactor-E, Norit</i>	32.000	0.69	6.2	6.6	6.0
CB	UV-(solar PV energy), macro filter	<i>Naiade, Clean Water Now</i>	2.000	0.59	5.8	5.7	6.5
	Ultra-filter; hypochlorous (electrolyse)	<i>WaterPurifier</i>	600	1.21	5.7	6.1	5.0
	Chlorine production (electrolysis)	<i>WATA (mini)</i>	(4800)	0.02	4.9	5.3	5.8
Quality distribution							
	good/green		green	6	7	7	7
	medium/orange		orange	9	9	9	6
	poor/red		red	6	5	5	8

* The overall AT score is using the weight of the criteria and is not by definition the average of the sub-scores

** Post treatment application only

Table 1: Summary of small-scale treatment options and their validation (from: NWP (2010) Smart Disinfection Solutions)

BB = Best Buy (very good performance (all >6.5) and within price level of € 2/m³)

CB = Cheapest Buy (low price level at acceptable appropriateness level (all sub-scores >5.5))

References

Water source options

Water storage options

Water treatment options

Sanitation options

APPENDIX : SANITATION OPTIONS

Sanitation cases:

- A. Dry toilets
- B. Water flushed toilets
- C. Urinals
- D. Storage/conveyance

No cost indications are provided for the below-mentioned examples. Costs are very variable and heavily dependent on labour tariffs, voluntary work and the final design.

A. Dry toilets

Dry toilets have no water flush. They mostly have a drop hole vertically below the seat or hole. Pits can be lined if the soil is unstable or when groundwater contamination is a risk. Size/depth of pit holes will depend on the intensity of use, the possibilities for emptying and the groundwater level. Superstructures can be simple or more sophisticated, depending on the economic situation and the risk of vandalism. The dropping point can be a squatting hole with foot supports (in the more modern style of a French or a Turkish toilet) or a raised seat/squatting pan.

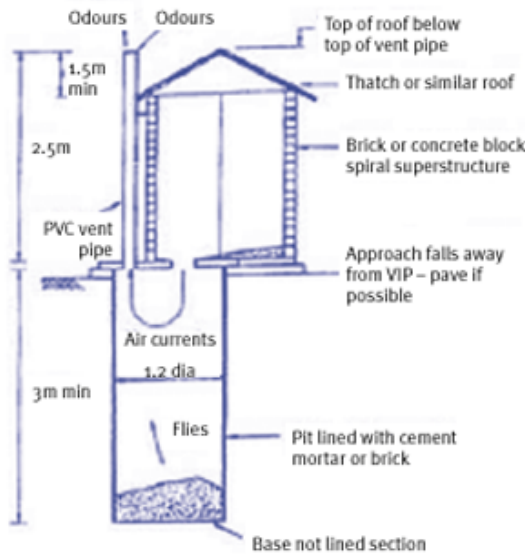
Arbo-loo



A simple shallow low cost toilet. The superstructure is movable. The drop hole is shallow. When the pit is full, the superstructure is moved to a new pit and the old pit is covered with soil and a tree is planted. Take care that trees are not planted too close to buildings as roots may damage the foundation in the years after.

The Arbo-loo can only be built as a standalone latrine.

Simple VIP-latrine



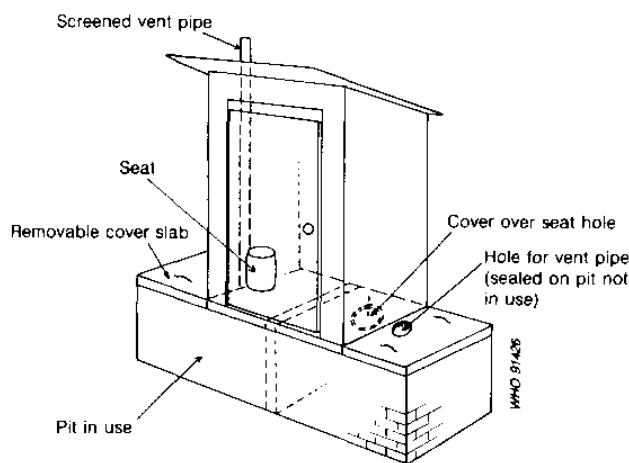
A series of separate VIP latrines is quite common. It is essential that they have a Vent pipe, covered with a fly screen. The base/floor should be stable and smooth, for which the use of a sanplat is recommended.

The rectangular design is the most common but in Zimbabwe the Blair or Elephants latrine has a curved entrance, which eliminates the costly door.

The VIP-latrine can also be built in series inside a larger sanitation building.

(Water Aid)

Double Vault VIP-latrine



This VIP latrine has 2 alternative holes, connected to two different pits. When one pit is full, the hole is switched and the sludge in the first hole can remain untouched. After one year this hole can be emptied without health risk. Most double vault latrines are used in eco-sanitation as a composting toilet.

The double vault VIP-latrine can also be built in series inside a larger sanitation building.

Xipoti modular latrine



A more sophisticated pit latrine with a plastic floor, a plastic seat with cover. Additional parts can be a child seat and a urine diversion.

The Xipoti was developed in South Africa (Envirosan) and introduced in Mozambique.

Kentainers Kenya is also producing similar models.

The Xipoti-latrine can also be built in series inside a larger sanitation building.

Plastic mobile latrine



A prefab mobile plastic sanitation unit. One advantage is the easy cleaning and the easy moving when the pit is full but a disadvantage is the poor ventilation with consequent heat and smell.

These prefabs work both as stand-alone and block units and they are also available with urine diversion.

They are produced by Kentainers in Kenya, Aquasan and other companies.

The plastic mobile latrine can only be used as stand alone, but can also be put in series.

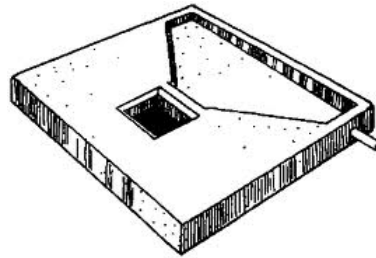
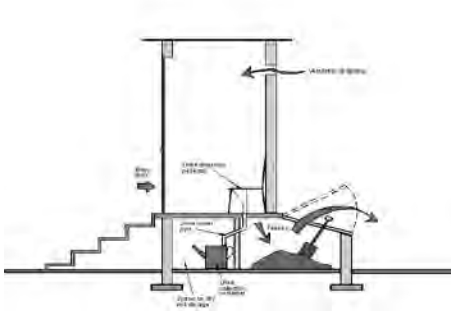
Dry composting toilets



Dry composting toilets have a double vault system with alternative holes. When one box is full, the hole is switched. Due to exposure to sun heat on black plates, the composting process is quick and after some months, the black soil can be removed as safe compost. This technology can be used with urine diversion.

Dry composting toilets can be put in series

Dry Ecosan Separation toilets



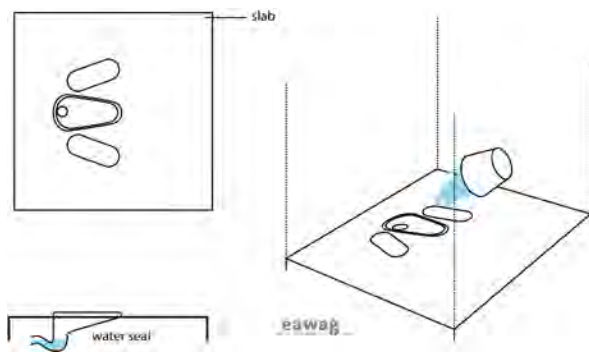
The principle of ecosan separation toilets is that the urine is diverted and the faeces are collected. There are many devices that separate urine from faeces. They can be built into the squat-hole of a sanplat or in the squat pan of a seat. The faeces can be collected in a composting chamber or in a removable bucket (or bag), that is easily accessible. In the latter case, care should be taken with handling the buckets. The urine can be drained to a flower field or to a jerry can.

Dry composting toilets can be put in series

B. Water flushed toilets

Water flushed toilets are very common in the western world and in Asia. They are considered as hygienic, but need good cleaning and presence of water. The water seal prevents odours and children need not fear falling in. Another advantage of water-flushed toilets is that the collection pit does not have to be below the hole and superstructure, but can be next to it, which might improve stability. A major disadvantage is the enormous water demand and the additional need for large sewer or storage capacity of the sludge/waste water. Blockage by solid waste or excess paper is a common problem.

Pour flush toilets

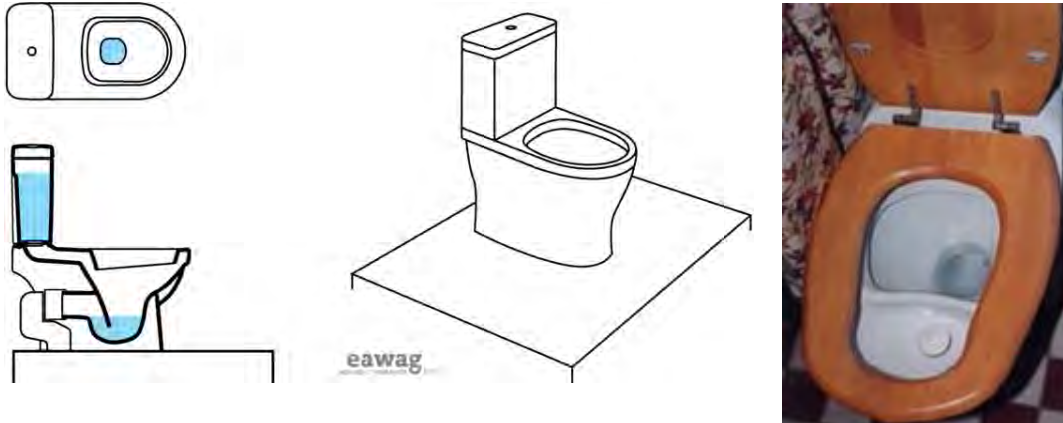


Pour flush toilets are very common in Asia, where water is also used for anal cleansing. They have a small shallow water seal. Urine diversion is possible. The S-shape of the water seal determines how much water is needed for flushing. To reduce water requirements, it is advisable to collect toilet paper or other dry cleansing materials separately.

The water seal at the bottom of the Pour Flush Toilet or pan should have a slope of 25 to 30°. Water seals should be made out of plastic or ceramic to prevent clogs and to make cleaning easier (concrete may clog more easily if it is rough or textured). The optimal depth of the water seal is approximately 2cm to minimize the water required to flush the excreta. The trap should be approximately 7cm in diameter.

The Pour Flush Toilet requires (much) less water than a traditional cistern Flush Toilet. However, because a smaller amount of water is used, the Pour Flush Toilet may clog more easily and thus require more maintenance.

Flush Toilets

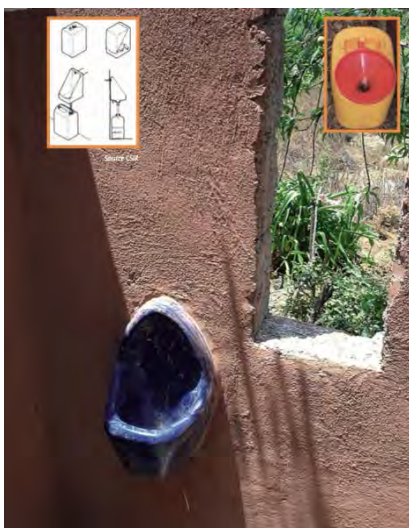


Flush toilets are considered as 'modern' and 'sophisticated' and associated with wealth. They need about 7-10 litres to flush. Water saving devices are possible if one has to flush urine only. Hygiene measures can be taken to protect the seat. In some cultures, pupils have to learn not to sit with their feet on top of the seat.

C. Urinals

Urinals can be for boys and in some countries also for girls. They can be flushed with water, but can also be 'dry'. They can be single/individual or for groups (walls). The urine can be kept separate and be used in agriculture/gardening by direct drainage or by bringing the collected urine to the garden.

Dry individual urinal



Example of Wall mounted urinal, Mexico (photo WASTE), Insert: "Eco-lily" in Ethiopia (photo SUDEA).

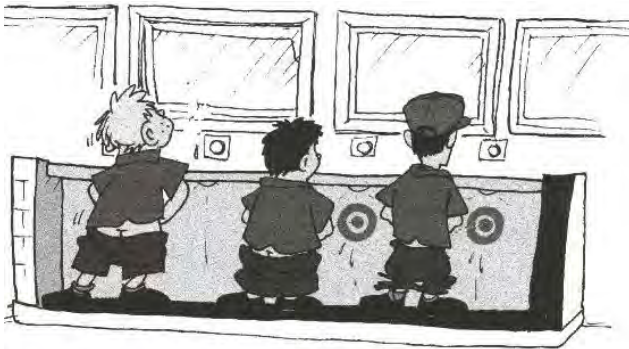
Girls urinal (examples)



In some countries, girls can also use urinals. The example shows a girls' urinal on a jerry can and a girls' urine gutter. The individual urinal needs to have more length than the boys' one.

Teenage girls prefer some privacy that can be provided with separation walls.

Urine gutter/shared urinals



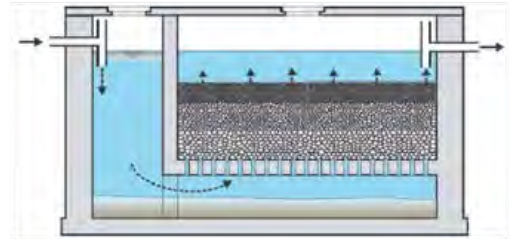
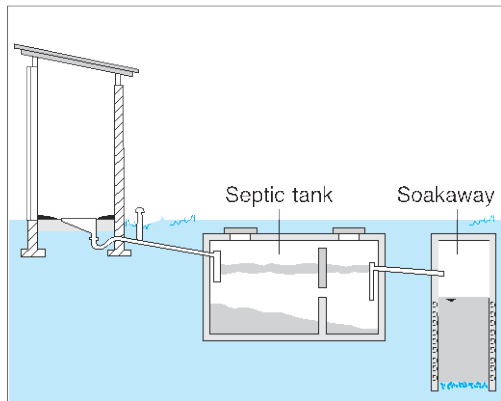
The boys' urine gutter is a cost saving device. They can be wet or dry. Care should be taken with splashing. Some boys and some cultures require more privacy than others.

D. Storage and conveyance

The most common storage is a 'dry' pit, or the composting chamber.

More sophisticated models are shown below.

Septic tank



Most water based institutional systems collect the grey and black waste water in a septic tank. Most septic tanks have a double compartment, connected through a hole at some depth in the separation wall. There is some removal of pathogens. The overflow is drained into a soak away.

Major problem with septic tanks is that they are rarely emptied. The consequence is that the treatment efficiency is reduced and the sludge runs straight into the (clogged) soak away.

An up-flow septic tank has a higher efficiency, but requires better maintenance.

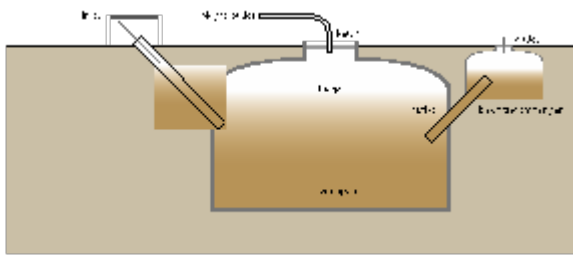
Anaerobe (bio-gas production)



Eawag, India (4 m³ institutional tank)



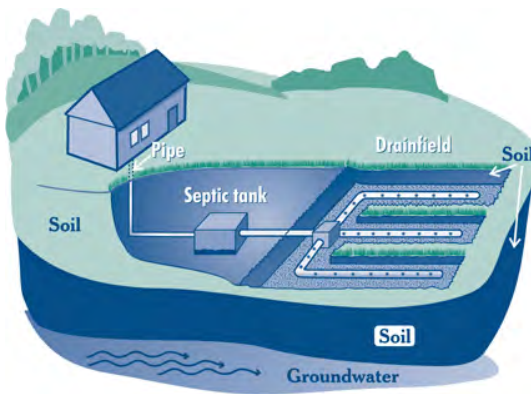
Biogas breeders and digesters at Gachoire Girls Secondary School in Kiambu, Central Kenya, process human waste from the school into biogas for cooking, saving money and trees. ALERTNET/Pius Sawa



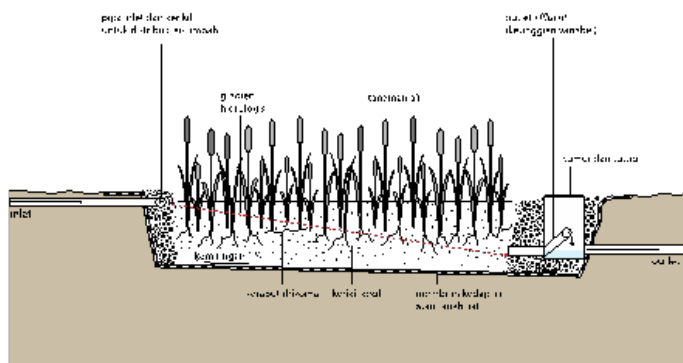
Bio-gas production is one of the options for environmental friendly schools, in which waste is reduced, wood logging is prevented and energy is produced (cost saving).

Most bio-gas units do require kitchen waste next to human excreta for effective gas production.

Drain fields and constructed wetlands



Instead of soaking away, the overflow/drainage of the septic tank can be connected to a drain field. The disadvantage is that the nitrate rich water still drains into the ground water.



If the area is sealed, And covered with reeds or other vegetation, the nitrogen's are bound and the water becomes much better treated (and can even be drained into surface water. This can be known as a helophyte filter or constructed wetland.



Grey water treatment



Water from showers, laundry and kitchen is considered as 'grey water' and may contain pathogens, but in a much lower concentration than 'black water' from toilet blocks. Simple filtering of this grey water is recommended before it is used for gardening.