WASH solutions for schools

A hand-out for the ARC Water Schools Programme

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This publication is still a draft and for internal circulation

Information taken from the publication can already be used after having got permission of EMF, as there seems to be a high demand under different WASH in schools initiatives.

Colofon

This hand out was made by Dick Bouman of Aqua for All, Henk Holtslag and Frederik Claasen of EMF as a contribution to the ARC program on waterschools. This program intends to stimulate the water and sanitation situation at religious schools. In many countries, these schools receive little funding. They possess a wealth of cultural/religious background to give an extra dimension to water and sanitation. In 2000, UNICEF published its Vision 21 in which it defined the target that 80% of the schools in developing countries would have hygienic water and sanitiation facilities. Without involving faith based schools, this target will never be attained. The Hand out consists of a short step by step approach, followed by a more elaborate back ground document.

Photo cover: Water for Life/Wetterskip Fryslan: Hygiene campaign in South Moçambique

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Step by Step Approach

Golden rules:

- Involve all stakeholders in preparatory process and decision taking! 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 planning for the preparation. Involve parents, teachers, pupils, special groups, technicians and create a good gender balance.

P2. Determine the present WASH situation at the school and try to focus at one (or two) step higher

Level	Typical situation
○○○○○	No safe water, no hygienic sanitation and/or no handwash facilities
●○○○○	Water can be treated at school, defecation area well protected and maintained and good handwash facilities with water and soap (or ash); hygiene education at school
●●○○○	Water collected from nearby safe source, pit latrines for each 50-75 children and good handwash facilities with water and soap (or ash); hygiene education at school
●●●○○	Safe water in school compound (>3 l/cap for drinking and hand washing); basic sanitation blocks (25-50 per seat); good hand wash facilities with water and soap (or ash); hygiene education at school
●●●●○	Safe water point near classes with > 5 l/cap for drinking and hand washing; well designed sanitation blocks (25 girls per seat; some adapted for disabilities); handwash facilities at all critical points; school led total sanitation/PHAST
●●●●●	Safe water point near classes with > 5 l/cap for drinking and hand washing; well designed sanitation blocks (25 girls per seat; some adapted for disabilities); hand was facilities at all critical points; water saving through re-use; school led total sanitation/PHAST

P3. What is the demography of the school (nr male/female teachers, nr girls (4-11, 12-18) nr boys (4-11, 12-18). How many pupils/teachers with (physical) deficiencies (and what type)? What is the growth prognosis in 10 years?

P4. How many classes are there now and what are the 10 year plans? What is the (ground) size of the hardened roofs? Are there gutters available?

P5. What is the present nr 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, neighboring 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/mosk/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?
- Has the school experience with tender procedures?

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 planning (time, people, communication, funding, 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 as;. Distinguish two options: (A) minimum option for drinking and limited other use like hand washing (2-4 liter/pupil/day) and (B) most desirable option (also water for cleaning, cooking, toilets etc. 10-20 liter/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, rain water 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. Take 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 €/liter or €/m3 and in € 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. Mind that a solution for 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 came up from the 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 max number of users, group division, and for each group the 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 an option and there is a desire to explore other types of re-use.

S2: determine for ***dimensioning*** the number of users (gender and age specific) and the volume of excreta and urine produced per day/per year or per emptying cycle.

S3: Determine possible ***limiting factors*** with regard to soil/rock, risk of inundation and space. Pre-indicate the possible ***sites*** for the sanitary units and possible storage and treatment. Mind 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 short list of relevant factors, like availability of water, soil type.

S4: Define the ***desired situation*** if money was not a problem and define the ***'intermediate' steps***, which might be affordable and acceptable. 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. An intermediate step may be just to build two more pit latrines: one extra for girls and one for boys.

S5: Enter into the ***design evaluation process*** for each part of the chain, being the 'toilet'/superstructure, the collector, possible transportation/conveyance, possible treatment and possible re-use. For this purpose one can use the web-based Decision Support Tool of Waste and Akvo (www.akvo.org – sanitation portal). Possible options 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: Define with the most relevant stakeholders for the selected chain elements the most relevant design parameters that came up from the discussions (related to target groups, age level etc.) and hand these specifications/list of preferences to a design engineer.

Follow-up:

- Make a final plan: for construction phase and for Operation&Maintenance phase
- Secure funding
- Tendering and contracting
- Supervision
- Monitoring

1. Introduction

This paper summarizes a number of ***technology solutions*** for schools on water, sanitation and hygiene facilities. Technology solutions are only part of the story: hygiene awareness, ownership and maintenance are equally important. Improving the water source will lead to 5% reduction of Under 5 mortality; hygiene education/practice and hand washing about 35%!.

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

Regarding sanitation basic requirements are

- at least one toilet per 75 children (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.

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

Covering the operational expenses is critical to ensure sustainable usage. These expenses must be part of the school budget. Some solutions even provide the opportunity to generate income themselves.

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. Children (and the surrounding populations) can be vandalistic, especially in sub-urbs. There can be a rapid rotation of pupils and staff, which makes sustainable maintenance a challenge. And mostly, the expenses have to compete with other priority items at the school budget.

Young children are afraid for a dark latrine and all the possible insects, reptiles and small animals around. Many of them are afraid to fall into the hole. One third is afraid for magic powers in the hole and 14% is 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 hand pump or to open a tap. And they are too small to reach common taps and hand pump handles. An example. The play pump (a merry go round) is an enjoyable invention, but might become an offence to children rights if they have to pump for the community, as well.

Before starting a selection process for the best technology solution, one should know whether there was an ***existing system***, and if so what are the reasons of disfunctioning (or functioning) and what is to be learned from that. For a non working system rehabilitation might be a possible option.

The final technology choice will depend on a wide number of ***factors***, like the available financial resources, demand; the available water sources; the physical, socio-cultural, economic and institutional environment, the existing infra-structure and 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 ***re-current 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 the 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 ground water with a well or borehole is too expensive, 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. However, they may host insects and they hamper effective rain fall for rainwater harvesting and leaves may contaminate and block the system.*
7. Availability of a ***reliable energy source;*** Manual/muscle power, Electricity, 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. *Hand pumps on wells are not easily accepted in Papua New Guinea, because women are not allowed to stand above a water source. 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 ***spares 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 sub-urb (destruction or theft). In case of frequent inundations, sanitation facilities should be raised to prevent the excreta to float out of the pits. Even better are facilities that can remain in use, even when flooded.*
13. The chosen technology should be ***easy in use*** (specifically for children) and ***easy to clean***. Smooth surfaces are important.
14. The need to make facilities accessible for ***disabled people***. There are several good hand outs on this (WEDC, Briefing Note 1; Share/Water Aid, Unicef)
15. Choice for ***sustainability/planet***; environmentally friendliness (e.g. no or limited use of fuels and chemicals)

Whatever technology is chosen, the most critical aspect is operation and maintenance. Some 50% of communal water points in Sub-Sahara Africa is not functioning. Essential criteria are ownership, availability of funds, capacity and will for good operation and maintenance.

One of the points to consider is to start a more ***centralized ‘maintenance’ service***, which may also be the owner of facilities. This is especially feasible in areas with a high population density. Example by CSIR/Kevin Wall in Eastern Cape Province (RSA) with over 400 schools.

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 are often different to what individual families can afford. For example water treatment with small filters could also be an option for families, but a rooftop harvesting system with a ferro cement tank is often too expensive at family level

The water schools initiative of ARC (www.waterschools.org) is part of the UNICEF initiative of Wash in schools. There are several other ‘communities’, actions and organizations that focus on water, sanitation and hygiene at schools. If you want to explore further, please consult:

- FRESH (under Unesco): www.unesco.org/education/fresh
- WASH in schools (Unicef and IRC) www.washinschools.info
- PLAN
- Safe the children,

Chapter 2 and 3 elaborate the steps to come to a proper choice of water and sanitation facilities. Mind that the hand washing device is included in the water chapter

After the selection of the best facility, one enters into the follow-up phases of final design (and Bill of Quantities), budgeting and fund raising, selection and contracting of the contractor, implementation and supervision and final reporting. Mostly, this process is to be guided by a consultant/construction engineer. Tendering is mostly the preferred option to get a good price/quality ratio. *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) got a training on quality standards.*

Meanwhile one should make an ***operation and maintenance plan***. Preferably this is done before the final version of the design report. Then it can also serve as a last check on feasibility (financially, technically and organizationally). Capacity building and training is an essential element. Arrangements with external parties need to be established.

2. Water

2.1 Introduction

Regarding water ***basic quantities required*** for day schools per child and staff are provided by UNICEF (2009):

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

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

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

Multiple use can be considered. For instance if a system is designed for drinking water and domestic use, consider to make it a bit bigger to have water for irrigation of a school garden. This can (partly) cover operational expenses and contribute to food security.

Water is regarded to be ***safe*** when it has no harmful micro-organisms like pathogens (e.g. E.Coli bacteria and viruses related to feces) and when the chemical substances are within the limits, established by the WHO guidelines (see table). Some of these guidelines are specified for children. For example: the maximum acceptable daily intake of fluoride is related to the body weight. Except for radioactivity, physical contamination (organic material, sand or clay) is in itself not harmful, but may hamper the effectiveness of treatment methods and may influence the taste and acceptance.

Common contamination and a major cause of 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. 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 reduce also viruses but the more affordable filter models do not guarantee that sufficient viruses are eliminated. To eliminate viruses, filtering needs to be combined with chlorination, or boiling is needed. Take into account that Chlorine will not eliminate protozoa. The concentration of harmful micro-organisms makes the infection. A healthy body can tolerate much higher concentrations of pathogens than a sick or malnourished child. Drinking contaminated water on an empty stomach is much more infective than in a filled stomach which has created a very acid environment. Eating before drinking (untreated water) is recommended. In general water filters do not fully eliminate all micro-organisms but will reduce the number.

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

Substance	Limit	unit	degree of harm	Remark	measurement	ease of treatment	Treatment method
E-Coli bacteria	5	counts/ 100 ml	high	Officially max is zero.	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, destillation
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 iresidual is 0.2-1 mg/l			
Chloride (Cl)			low			difficult	
Fluoride (Fl)	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	aestehic			
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 rain water harvesting (in combination with treatment). An ‘improved source’ is however no guarantee for safety. A recent UNICEF study in 6 countries found that at the moment of measurement 10% of the water from taps and 30-60% of the so-called other improved sources (JMP 2010, RADWQ survey) was unsafe.

Water that is safe at the source can easily get ***(re-)contaminated*** before the point where it is used. This is caused by the use of contaminated cups, containers and hands, or by 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 openings need to be protected with mosquito wire.

If no safe water source is available, or when there is a safe water source but 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 (slow sand/biosand filters). Application of too much chlorine might be harmful. Turbid water needs pre-treatment to remove the suspended particles. This can be done by coagulation/flocculation, sedimentation or pre-filtration.

Water with too high content of certain minerals needs special treatment. This is especially true for Arsenic, Fluoride, Nitrate and heavy metals. Mind that the water taken at schools is only part of the daily intake. Removal of minerals is often complicated for a school application, except for some minerals like iron and manganese (through oxidation).

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

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.

Water testing

Water quality can be tested with different methods.

Contamination with ***fecal micro-organisms*** is mostly tested by measuring the presence of E-Coli bacteria, often by 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$. Some of these tests indicate the presence of harmful bacteria, the other provides a more quantitative measure. All tests take some hours to a day. Regrettably the tests are too expensive to apply as a regular measurement at single schools.
The total salt content of the water is mostly tested by measuring the conductivity of the water, expressed as EC (Electrical Conductivity) in µS/cm. Instruments can do many tests and can be obtained from US$ 30 and above. Water with an EC of 1.500 µS/cm or more is not recommend for drinking for too long.

Acidity (pH) is not so much a problem for health, but for the corroding effect on concrete and metal, especially in combination with low calcium content or presence of free CO_2. Instruments can do many tests and can be obtained from US$ 30 and above. Moreover, there are simple test strips or other method which cost less than US$ 0,10 each.

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

2.2 The water delivery chain

Depending the selected water source, the water delivery chain may consist of water source development and protection, a pumping device, a storage facility, a transport device, a central or decentral treatment facility, distribution, provision and drainage. A storage device can be at different points in the chain and some have a storage with pre-treated water and a storage with clean, safe water. Appendix I provides the full chain in relation to the selected water source. Try to think beyond the conventional solutions. There is much *literature* on different water facilities . www.akvo.org water portal/akvopedia may be a good entry and it refers to a lot of literature.

On next page there is a nice example of a complete water chain, even including the facilities for sanitation. This example is taken from Godfrey et al (2010) for the situation of rural India, where water use in a toilet is common, despite of semi-arid conditions. The example does not show some details, like pumping and treatment. Of interest is the use of excess rainwater for groundwater replenishment.

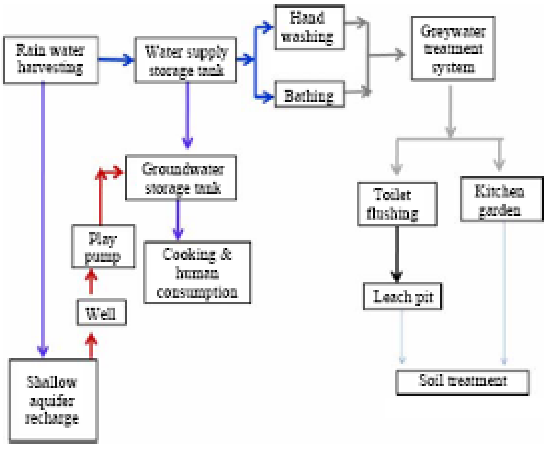

Figure 1: Example of a water supply chain from the Wise Water Management project in rural India (Godfrey et al (2010))

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 with a pumped or a gravity scheme. Water from these sources needs treatment. A screen at the inlet, a sediment trap, a pre-treatment unit and a point of use treatment are recommended.

Groundwater can come from natural springs, shallow (hand dug) wells and machine or manually drilled boreholes. Wells need to be covered with a cover and boreholes with 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. 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.

Rain water can be harvested from roofs and paved surfaces. Rain water can be collected from roofs with gutters and collected in storage tanks. Another option is to use normal or hardened surfaces and collect water in an underground storage tank. This option certainly needs a sediment trap. Water treatment can either be done in or near the storage or at the point of use with disinfection and /or water filters.

Rain water 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 filtrating in the ground is planting trees with plants like Vetiver 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 dry up in the dry season.

In general, the priority ranking is as follows:

1.**Gravity systems.** Connection to a nearby spring and bring water to the school by gravity with pipes. Investment cost can be high 1.000 - 50.000 US$ but 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** in case this one 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 required and there is a risk the water maybe cut off in case of non payment.

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 may be the insecurity for small children and girls. A wheel-chart with containers might ease the supply to the 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 in general where water levels are deeper than 15 meters. Depending on the type of hand pump a shallow hand dug well with hand pump costs € 500 - € 4.000 (Africa).

5. **Deep well/borehole**. Disadvantages are 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. New drilling methods and low cost and locally produced hand pumps can in some situations be an option. An example is in the South of Tanzania (Njombe). School water points there consist of a manually drilled borehole and a rope pump at 40 m deep. Total cost € 650 – 800. A good website for guidance on boreholes and handpumps is www.rwsn.ch

Water pumping

Wells and boreholes need ***pumps***. These can range from simple foot operated suction pumps, manually operated pumps like rope pumps, manual piston pumps (Nira, Indian Mark 2, Afridef, 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. The selection of well or borehole and the type of pump should be done by a specialist.

Hand pumps exist in different types and capacities. Suction pumps can pump up water from a maximum depth of 5-7 m. Direct action piston pumps like Nira or Canzee pump can pump from 10-20 m (but might be heavy for children). Piston hand pumps like Afridef and Indian Mark II and rope pumps can pump from 3 to 50 meters deep, and pumps like Volanta and Blue pump can pump from boreholes to 60-100 meters deep. In general maintenance of these pumps has to be done by specialists.

Electric pumps and some types of hand pump 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.

Lifting water from an underground water reservoir can be done with a simple suction pump, as long as the water level is not deeper than 7 m.

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 set of pumps 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.

Water Storage

Water storage is often required to create a buffer between the peaks in the supply and the peaks in the demand, whether on daily or seasonal basis. Moreover, (overhead) tanks can be used to create (constant) pressure in taps. And in some cases, water 'storage' can be used for the settlement of suspended particles. There are many different tank types, from the traditional masonry and concrete ones to the cheaper ferro-cement, or wire cement types which are made with wire, cement local materials like bamboo, bricks or clay. These options are more economic than the traditional concrete tanks. Another option is a plastic tank of 500 to 5,000 liter, but these are rather expensive and need protection against sun light.. A recent development is strong plastic bags (foldable tanks) as now used in Uganda. Other 'cheaper' solutions are pre-fab tanks of metal sheets, lined with plastic. These tanks can be of a very large volume and can be roofed.

	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 m3= € 6.100
foldable bags	27	1.5	Enterprise Works, Uganda
prefab sheets with lining	90-150	100-500	ex factory; Bucon; 100 m3 ex factory NL = €12.000

Table 2: Summary of tank types and their unit prices (Africa)

A water tank is recommended to have a wash out (to ease regular cleaning and to flush the sediments) and a regulated overflow (in case the inflow is too high). Tanks should be combined with entrance and outlet valves. An automatic floating valve (which closes when the tank is full) is recommended. Openings (vent pipe, overflow and others) should be protected against insects and animals (with mosquito wire). For the water used for drinking it is recommended to use a treatment at the outlet (e.g. a membrane filter) of a Point of Use treatment option like disinfection or a water filter.

Water conveyance

Water conveyance can be manually or through (closed) pipes. Manual transport is to be done in clean jerry cans or containers that can be closed to avoid contamination. 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, poly ethylene; in sequence of price), diameters (inches or mm) and pressure class (10 meter water pressure = 1 Atmosphere). Not all plastics are UV-resistant (sunlight). Pipes are preferably buried into the ground to avoid damage and to avoid that water is at high temperatures for too long (risk of virus growth like legionella).

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

Water treatment

Water treatment is required for all surface waters and sometimes for groundwater, spring water or rain water. As mentioned, water may get re-contaminated during transport and storage, 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). During the time that there is no pressure (or under-pressure), contaminated groundwater may enter into the pipes. To avoid regrowth of algae and bacteria, mostly chlorine is applied (4 mg of free chlorine per liter). A newer and less known option is colloidal silver which is less problematic for health (see below). Centralized treatment can be done by the water company/ supplier. Decentralized treatment options are plants like Perfector, Water maker, Naiade etc. These systems have capacities of 500 to 50.000 liters 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 in :

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** do combine the physical filtering of the sieved sand and 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. Boiling has disadvantages like cost of fuel, indoor pollution, requires time 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 are flask with liquid (Waterguard, Certeza) and tablets like Aguatabs. Chlorine can be locally made by the electrolysis of salty water (e.g. by using the WATA). Another disinfectant is silver which is in comparison to chlorine not toxic, does not have a smell or taste and has a long shelf live, whereas it can eliminate all harmful bacteria. There is Silver in liquid form like Silverdyne and as a float ceramic sphere like Plation. Several companies are further developing this promising option.
5. Products that use **combinations** of the above mentioned technologies such as the Pureit filter.

A wide sample of 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, Tulip , eliminate turbidity and up to 99.99 % of all harmful bacteria. Ceramic pot filters eliminate turbidity and reduce bacteria with 90 to 99% and biosand filters reduce turbidity and bacteria with 50 to 98 %. New generation filters like the Tulip or Life straw family model have high filter speeds of 80 to 150 liters 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 liter. Like other technologies training in maintenance is essential

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

Figure 1: Sample of small scale disinfection products

Best/Cheap Buy	Product process, removal agent	Product name, brand	Capacity ltr/day	Unit price €/m³	Overall AT-score *	Sub-score Performance	Sub-score Planet/People
	Limited virus and bacetria reduction						
	Plation floats (ceramic silver balls) **	*AquaEst*	(50)	€ 0,75	6,6	6,1	7,0
	Biosand filter	*CAWST; Hydraid*	100	€ 0,11	6,4	5,7	8,0
	Arsenic reducing biofilter	*Kanchan, ENPHO*	50-75	€ 0,11	6,1	5,3	7,0
	Limited virus reduction						
BB	Ceramic Silver Pot Filter	*Potters for Peace*	15-30	€ 0,57	7,9	7,9	8,0
CB	Ceramic/carbon candle	*Water4Life*	25-50	€ 0,42	6,3	5,7	5,5
CB	Siphon ceramic silver filter	*Tulip, Basic Water Needs*	50-80	€ 0,51	6,1	6,1	5,5
	Plation Rain Purification Centre	*AquaEst RainPC*	275	€ 2,00	5,4	5,7	5,0
	Slow Sand Filter	*e.g. Jal Tara*	(2.750)	€ 0,22	5,2	4,4	7,0
	Good virus reduction, individual-family size						
	Chlorine drops, hypochlorite	*e.g. Safe Water Storage*	NA	€ 0,24	7,0	8,3	4,6
BB	Solar UV - PET bottles	*SODIS*	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 **	*NADCC aquatabs*	NA	€ 3,25	6,5	7,9	4,6
	Sachets flocculant/disinfectant	*PUR, Procter&Gamble*	NA	€ 7,14	6,5	7,9	4,6
	Solar UV/IR heat, plastic bag	*Aquapak*	5	€ 3,13	6,4	6,1	6,0
	Iodine & micro-filter in suction 'straw'	*Lifestraw, Vestergaard*	1 (max 10)	€ 4,08	6,4	6,1	6,3
	Iodine & ultrafilter, gravity	*Lifestraw, Vestergaard*	15 (max 150)	€ 0,79	5,3	4,9	5,2
	Carbon, filter, chlorine	*Pureit, Unilever*	20	€ 4,35	5,1	5,3	5,0
	Good virus reduction, group size						
CB	Multi-filter and UV	*Perfector-E, Norit*	32.000	€ 0,69	6,2	6,6	6,0
CB	UV-(solar PV energy), macro filter	*Naiade, Clean Water Now*	2.000	€ 0,59	5,8	5,7	6,5
	Ultra-filter; hypochlorous (electrolyse)	*WaterPurifier*	600	€ 1,21	5,7	6,1	5,0
	Chlorine production (electrolysis)	*WATA (mini)*	(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: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/m^3)

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

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 *anorganic chemical elements* can be easily removed, but most of them need sophisticated devices and hence skilled staff. Much care should be given to Arsenic, Fluoride and Nitrates.

More information in disinfection see Smart Disinfection Solutions

Mind that much can be done by *prevention*. This can be done by the full coverage of spring box or well heads and the avoidance of entry of drainage water. For rain water, one should install a sieve and a first flush device before the entry of the storage tank. Tap water should be collected in safe jars/ jerrycans/ containers, which can be closed..

Water provision

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

- One option is to provide drinking water in a canteen or in the class room 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).
- It should be avoided that pupils touch the water with hands or dirty cups. This can be done by using storage tanks with a lid and a tap or by using bottles or a kettle. A spoon to take water form a container is not recommended, because this gets easily contaminated in a school environment.
- Preferably, each pupil has its own cup or plastic bottle, which is regularly cleaned. If there is only one cup, this should be cleaned after each use.
- The drinking function is better not mixed with the other functions of water, like toilet units and hand washing, because these other devices get easily contaminated.
- Discourage pupils to drink straight from a tap, or use their hands as cups.
- Care is to be taken not to spoil water. A leaking tap can drain a full tank, even if it looks minimal.

Hand washing facilities are very important to improve health at schools. Hand washing with soap even may be more effective in the reduction of diarrhea 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 location is preferably near the toilet. But there should also a facility near the school building if hands have to 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.
- Minor children need to be able to use it (size and ease of use). This might be done by an optional step near the device.
- Recontamination of fingers/hand may take place by retouching the tap with the fingers or by using a shared towel. This should be avoided. The former can be avoided by teaching children to close the tap in a different way (e.g. 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 very simple self closing devices. Tippy taps are opened by the feet.

- Drainage is very important. Children are discouraged to use the tap if they have to step into the mud.
- Water saving needs a lot of attention. A good example is a tippy tap, which is very economic in water use.

2.3 Water technology selection

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

Step 1: Water that is safe to drink and water for hand washing. Determine the ***water quantity*** per pupil per day and per year as;. Distinguish two options: (A) minimum option for drinking and limited other use like hand washing (2-4 liter/pupil/day) and (B) most desirable option (also water for cleaning, cooking, toilets etc).

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

Step 2: 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, rain water harvesting. If there is an old supply, one should 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?).

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 rain water 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		m2	%	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 the multiplied by the *average daily availability times number of users. In case of an 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 liters or 67 m^3 . Rationalization is required, right from the beginning.*

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

Step 3: ***Select*** the preferred alternatives from a water source perspective. Take a maximum of 3. In case of scarcity of water or limited funds, source separation 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 (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.

Step 5: 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 in the area of the school. Do not try technologies that are unknown in the area or innovations in isolation. Only if the selection is to be made by a large school program or project, existing or new innovative technologies from further away might be explored. For instance if a school is situated in an area whit ground layers were manual drilling is possible and water layers (aquifers) are expected to be less that 40 meters deep, hand drilled boreholes and simple hand pumps like a rope pump could be an option. However, if there are no local skills to do this, first a programme is needed to train the local technicians, workshops in these technologies. The same goes 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.

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'. 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 stormwater and Aqua for All/Akvo have started a tool for treatment options.

Step 6: Determine investment costs and operational costs and express them in €/liter 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 the options traditionally applied. Instead of hand digging or machine drilling, one might consider manual drilling methods. If expertise is not available programmes are needed to create expertise. One often sees that heavy duty hand pumps (like India Mark II/III or Afridev) are put on wells with shallow groundwater. There are now cheaper alternatives, which are also lighter to operate and more easy to repair (suction pumps like Jibon or Treadle pumps for water levels up to 5 m deep and direct action *pumps like Nira, Canzee, Mark 5 for water levels up to 12-20 meter, although at 20 meters they might be heavy to operate. For water levels to 40 meters deep, locally produced rope pumps can be used,.*

Sometimes, it may be more cost effective to invest in very robust and high quality technology when this reduces the maintenance costs. This is especially true for hand pumps with deep water levels. *For middle deep boreholes till 50 meters pumps like Afridef and Indan Mark 2 are advised and for deep boreholes, high quality pumps like Volanta and Blue pump are advised which can pump from boreholes down to 100 meters deep.*

Also for water storage and water treatment there are very low cost technologies available.

*See smart series on water harvesting and disinfection**

Cost	Unit	Evaluation	Remark
Lifetime	year	5	
capacity	l/day	50 - 80	
Volume in lifetime	m3	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: 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. Mind that a solution for both a community and a school has many advantages.

The relative higher investment of the shallow well option in appendix II is easily compensated by the unit costs per m^3, due to the higher volume of the water source. Rain water 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, 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. Strange enough, it is often used for hygienic use only.

	Unit	Evaluation	Remark
Lifetime	year	10	
Capacity	l/day		
Volume in lifetime	m3	400	4 * 10yr * 10 m3
Investment	€	€ 1.000,00	incl gutters
Replacement during lifetime	€		NA
O&M lifetime	€	€ 200,00	cleaning
Salary cost lifetime	€		NA
Unit price	€/m3	€ 3,00	

Table 6: Example of cost calculation of rain water 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 came 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													Remarks
		Source	Collection	Lifting	Transport	Storage	Treatment						Provision	Drainage	alternatives
							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	Tank for 50% day use	Rare	Possible	Rare	Possible	Possible	Rare	taps at source or at school	attention	
public scheme nearby	reliability (daily and quality)	x	connection	x	pipes	recommendable overhead	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													Remarks
		Source	Collection	Lifting	Transport	Storage	Treatment						Provision	Drainage	alternatives
							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;		
selected option															
roof top with treatment	roof exsisting: 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 resistent	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 ($)						10					0		0	10	
Salary costs liftime ($)						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 ($)			0	25		0					0		0		
Salary costs liftime ($)			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 more than a decent toilet. It aims at the avoidance of contact between human beings and dangerous micro-organisms (pathogens) to prevent the spread of diseases, like diarrhea.

Regarding sanitation basic requirements are (UNICEF 2009):

- at least one toilet per 75 children (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 need 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 disposal of napkins). Also teachers have (preferably) a separate toilet. A good balance is to be found between enough distance between school building and sanitary unit (30 meters), visibility of the pathway and the need for privacy. Consideration should be given for adapted designs for ***disabled pupils***, whether poor sighted, or physically challenged. One in five poor people are disabled. The fact that there are no such students can be an indication that the school is not receptive for this group. In the design process, it is recommendable to include children, parents and teachers. Especially for sanitation, there are many taboos and the subject is very personal.

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. The school environment provides sufficient scale to exercise such innovations and has often some qualified staff to deal with this.

The construction of ***urinals*** needs to be considered. In some countries, even girls' urinals are applied. This is not only supporting the idea of re-use of urine, but it is very economic as it releases the pressure for the more expensive and time consuming common toilet. For minors, the height of urinals needs to be appropriate.

The school environment may challenge the children for change of habits and behavior, which might have a wider impact on their families and society as a whole. The school facilities may function as a ***demonstration***, but for a family level, the structures are often difficult to afford. Hence, the teaching of children and parents should also include alternatives for household level.

When selecting a solution, people tend to go for the highest standard, especially when externally funded. In our perspective, solutions need to fit in the local environment, and one should not build a toilet palace next to a school with a leaking roof, or worse. Especially, the recurrent cost are very important to consider. On the other hand, higher quality might reduce the maintenance and repair costs.

For this situation, the sanitation ladder might provide a guiding tool. One could define different levels from a simple pit latrine to a flushed toilet and everything in between. It is better to climb the ladder step by step than jumping onto the highest step at once. (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 for the 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 on 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 pre-fab or under the name sanplat; with or without urine diversion), a floor receptacle for poor 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* in 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. Frequent flushing with water is not required. For cleaning non drinkable water may be used.

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

- Preferably, the entrance of insects and animals should be prevented.
- When doors are applied, special attention is to be given to locking (from inside) and the strength of hinges. They should be wind proof. They should not be too heavy (for minor children). *When visiting a project in Kenya, all the doors of the latrines were damaged. By inspection it proofed that the carpenter had used nails instead of screws. Moreover, when doors were opened by the wind, the door was forced to the frames in such a way that a momentum was created, providing 20 times more force on the nails/hinges, which were easily taken out of the door frame.*
- Special attention is to be given to the stability of the structure and its foundation, especially because of the presence of the pit nearby, which might provide instability.
- The use of wood/bamboo at floor level needs to be avoided. 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 that they facilitate the cleaning (including a lowest drainage point).
- Consider the possibilities for cost saving by the use of alternative materials or design.
- In case of flood/inundation risks, the full structure needs to be raised to avoid the entrance of flood water into the building.

- Have a separate boys and girls compartment (and teachers). Mind 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 the hand washing facility
- Consider to use 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 $1m^2$)
- 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*** varies from simple pits below a pit latrine, a composting compartment and a septic tank to a combined wastewater treatment unit. For urine, a separate collector (jerry can or container) can be used. Urine can be used for the school garden and has 5 times more phosphate than feces. Urine can also be sold to neighboring farms. The pit/tank can be below the superstructure or next to the superstructure. In the last 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 that year, 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 sufficiently safe 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. In this case, rising ‘groundwater’ levels may lead to the overflow of pits, however. Raised superstructure can also be applied in case of a rocky sub-soil or where the sands are too loose for pit stability. Ecosan toilets, using both urine and feces, can be considered but in practice this is more complicated and has more cultural resistance.

More sophisticated systems combine storage and treatment. Examples are an anaerobic filter, an anaerobic baffled reactor or an anaerobic biogas reactor(see Akvo).

The Wise Water Management project in India develop 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, whereafter it is lead through a baffling tank for sedimentation, and two gravel/sand beds for further treatment, 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.

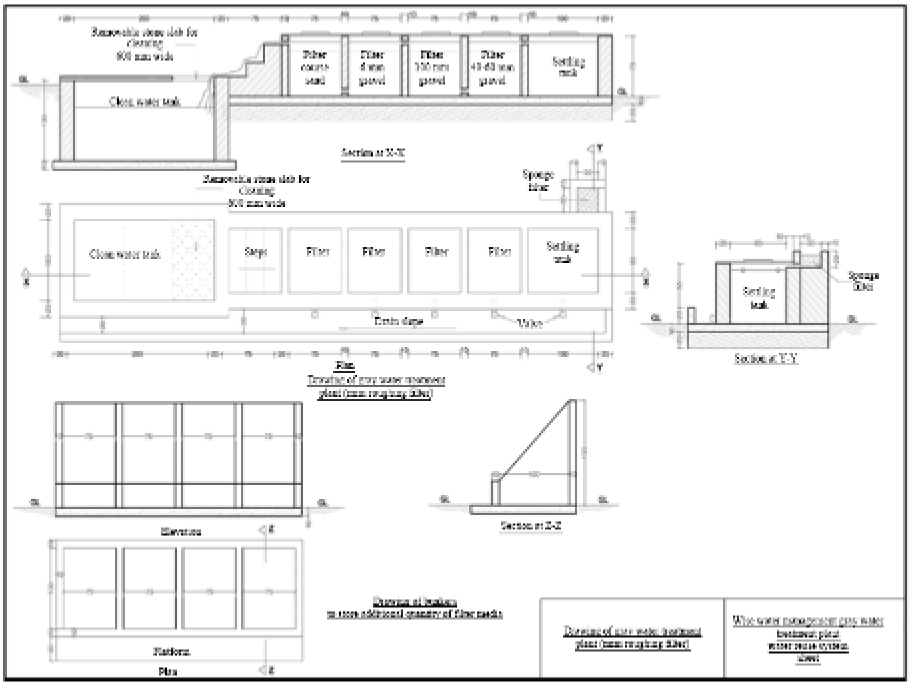

Figure 2: technical drawing of grey-water treatment in the Wise Water Management project in India (Godfrey et al 2010)

The water is filtered at 0,2 m3/m2 h through a gravel bed of 10-20 mm and one of 6-10 mm. The removal efficiency for most of the factors (turbidity, BOD, E.Coli) was around 50%.

The *dimensioning of the volume* of the pit/tank is essential to determine the life cycle or frequency for emptying (see 3.1). An adult living on an almost vegetarian diet produces about 145 kg of excreta per year and 400 liters of urine. For a meat diet, the weight of excreta is much lower. For children in a school situation, these figures may be much lower and around 15 kg of excreta and 60 liters of urine (own calculation/no figures found in literature; 5 days a week, holidays, much lower consumption, avoidance of toilet use during school time and short period of the day). The material used for anal cleaning and hygiene pads/napkins for adolescent girls, if dropped into the hole, should be included in the calculations. Preferably, non-degradable materials are put aside in a separate (covered) collector that is regularly emptied at a decent place. This will enlarge the life time of a pit. Access for desludging will also enlarge the lifetime and reduce the need for dislocation

In most literature it is recommended to *seal the walls* and floor of the pits to prevent contamination of groundwater. In most cases, however, the subsurface drainage water is cleaned by bacteria within 60 days. Moreover, the decomposting process is more rapid under dryer conditions. Only in case of nearby water wells or very shallow groundwater tables, this 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 meter above the roof, black painted and sun-exposed. The effectiveness of VIP-latrines is questioned by some experts, nowadays.

The ***conveyance of slurry*** (and urine) may be done through sewers, vacuum trucks or by transport of containers. The compost of composting toilets can be removed safely after one year without further precautions. Human contact with the fresh slurry needs to be avoided or protecting cloth needs to be applied. The overflow from septic tanks can be collected in a small bored system (small diameter pipes). For institutions like larger schools or boarding schools, the (pre-treated) overflow of the septic tank may be lead into a constructed wetland or helophyte filter, may be followed by 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. 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, to be used for the school kitchen or lightening. Pathogen free manure can be re-used in the school garden. Pre-treated waste water can be used in fish ponds. There is much literature on this issue, which goes beyond the purpose of this paper.

Many schools decide to make tree nurseries. One should realize that newly planted trees can grow quickly and their roots can easily destroy buildings and structures.

For ***boarding schools***, the standards need to be higher with regard to sanitation blocks and water availability for hygiene and sanitation. The same holds for washing, laundry and shower facilities. Provisions need to be available for sick children.

Investment Costs are in the order of € 1.000 per seat and € 15 per child, excluding water supply facilities, handwash facilities and hygiene education. The table below shows a summary of the data base 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 these steps are taken in a consultative or participatory process with children, parents and teachers in a good gender balance. For taboo issues, one might make a division between male and female groups. The steps are mainly derived from a Decision Support Tool, developed by WASTE and AKVO.

step 1: decide on the ***design criteria*** and the desired final destination of excreta and urine. Among the design criteria are max number of users, group division, and for each group the 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 an option and there is a desire to explore other types of re-use.

step 2: determine for ***dimensioning*** 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 space. Pre-indicate the possible ***sites*** for the sanitary units and possible storage and treatment. Mind 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 short list of relevant factors, like availability of water, soil type.

step 4: Define the ***desired situation*** if money was not a problem and define the ***'intermediate' steps***, which might be affordable and acceptable. 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. An intermediate step may be just 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, being the 'toilet'/superstructure, the collector, possible transportation/conveyance, possible treatment and possible re-use. For this purpose one can use the web-based Decision Support Tool of Waste and Akvo (http://waste-dev.akvo.org/). Possible options can also be found on the Akvo website; sanitation portal.

step 6: Make a choice from the selected chain options, based on technical, economical and cultural criteria and feasibility criteria (see chapter 1).

step 7: Define with the most relevant stakeholders for the selected chain elements the most relevant design parameters that came up from the discussions (related to target groups, age level etc.) and hand these specifications/list of preferences to a 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

In this paper, hygiene is linked to water and sanitation as a means to break the so-called F-cycle which facilitates the transmission of dangerous micro-organisms from faces to mouth. The cycle includes transmission through dirty fingers, flies, food, floor (soil) and fluids (water). Sanitation reduces the first contact, water treatment the transmission line through water and hygiene the transmission through other paths. Hygiene education and effective use of hand washing facilities reduce the mortality figure for Under 5 Children with about 37%.

Hygiene can also be a link to other aspects, such as health, nutrition, body hygiene, sexuality, environment and housing/habitat. This paper will not explore all these different aspects. Prevention is a very important issue (such as cleanliness, health consults and vaccination), but also health treatment (such as the very cost effective deworming campaigns) and clothing (foot wear).

Hygiene is mainly education and behavioral change. Most literature on hygiene is concentrating on education methods. Value based education is also the major focus of Waterschools (ARC).

Hygienic behavior can 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 are linked to environmental measures against dust and mosquitoes, like elimination of ponding and open water, cutting trees in the direct vicinity of houses and schools (esp banana trees near schools), waste removal (esp. old tires and other material that may store water).

A hygiene/sanitation/habitat check can be recommended as the first step in a participatory design process, together with children, parents and teachers. The central question is to identify situations on the school compound that are good and that would need improvement from an environmental point of view. When participants express their top 5, the facilitator may invite the person to come with a solution, after which other might give alternative suggestions.

For the purpose of hand washing, one is referred to chapter 2.2.

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

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