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International Survey on Alternative Water Systems

Extended Summary

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Extended Summary*

1 Introduction

Conventional water systems, delivering supply water through pressurised pipe networks to the in-house tap, and disposing waste water through gravity sewer networks with centralised waste water purification, have gained a high standard of service, comfort and reliability. Anyhow, there is a growing demand for Alternative Water Systems, wherever the conventional systems are not affordable in terms of money or in terms of natural water resources.

Due to the urbanisation and desertification and population growth, the number of settlements which need Alternative Water Systems is rising dramatically. On the other hand, the technological and organisational development for such systems has reached a stage (and is still improving rapidly), where decentralised services, autonomous supply and new treatment processes have become competitive.

Therefore, the Federal Ministry for Education, Research and Technologies (BMBF) has awarded the Institute for Environmental Engineering and Management at the Private University of Witten/Herdecke (UWH - UTM), to carry out a quick international survey about ongoing research and pilot projects regarding Alternative Water Systems.

The authors and their staff would like to thank all colleagues and officials for excellent and very open co-operation, especially in Japan, USA, Peru, Kenya and Thailand, where onsite project visits were possible. Additionally, easy communication via e-mail made it possible to communicate with a number of experts and to participate in outstanding experiences from many places. The authors would like to express their sincere thanks to all of these professionals, who have contributed to this project.

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2 Motivation and criteria

Alternative Water Systems are unavoidable,

- whenever the population density is too low, so that the costs for centralised networks would become much too high (parameter: pipe meter per connection or per m^3 of annual water consumption),

- where the population density is too high, and the natural water sources in the region would not be sufficient to feed flushing toilets etc.,

- in the arid and dry zones of the world
  where water is scarce and water recycling is necessary,

- under extreme technical site conditions
  including mobile plants on ships, trains, planes, etc.,

- in case of political instabilities
  where public infrastructure is not working at acceptable standards
  (and it has to be understood that such situation is existing in many countries of Africa, East Europe, South America and Asia),

- whenever the customer is unable or unwilling to pay for the water tariffs needed to refinance conventional water systems.
  (in low income areas, sometimes 100 % of investment costs are subsidised by international donations, and the customer does not even pay for the operational costs of conventional water supply. In the opposite, many individuals in rich Western countries, like in Germany, are sometimes willing to pay much more for autonomous decentralised and "nature-styled" water plants than for water from a conventional system).

3 State of application

The following tables show, which solutions for alternative water systems are existing in water supply and sanitation.

Table 1: Existing Alternative Solutions for Water Supply [LdE '98, revised]

Type	Description	*Average Water Supply (L/C/D)*	No. of households supplied	Advantages	Disadvantages	Examples
Communal open wells.	A bucket attached to the end of a rope is used to draw water from a well.	10-50		In principle, cheap source of water (but can be fairly expensive taking account of the cost of ropes, buckets, etc.).	High risk of contamination.	Dhaka
Tube wells/bore-holes	Pumps are attached to the top of a pipe which is sunk into an aquifer.			Clean water is available.	Reliability of pumps. Can be expensive to sink.	Dhaka, Jakarta
Water vendors	A vendor delivers water to the home.	5-50		Water is brought to the home.	Expensive. Quality of water supplied.	Jakarta, Maroua, Ho Chi Minh
Public tanker trucks.	Trucks deliver water to the home or close by.	5-50		Water is brought to the home or close by.	Expensive.	Phnom Penh
Water kiosks	An operator sells water from a kiosk, from where users have to carry it home.	5-20	100	Clean water is available. People only pay for water they use. Very high payment rate.	Expensive. People have to walk and carry long distances.	Port-au-Prince, Ouagadougou
Communal standpipes	A tap shared by many homes.	10-50	25	Cheaper installation than other systems - low bills.	People have to carry their water. Different methods of payment. Pay-ment problems.	Jakarta, Ouagadougou, Delhi
Yard or roof tanks	Water is drawn from tanks installed at each home; the tanks are filled daily.	30-50	1	Water is always paid for. People can judge the amount of water they are using.	Tank may empty if consumption is high.	Durban
Yard taps	Service pipe delivers water to tap situated in the yard.	30-100	1	Water is available on-site.	High investments.	
House connections.	Service pipes are laid to supply water direct to taps inside the home.	40-250	1	Very convenient.	Water use escalates. High investment costs.	City centres

Table 2: Existing Alternative Solutions for Sanitation [LdE '98, revised]

Type	Description	Average flush water volume (litres)	Advantages	Disadvantages	Examples
Ordinary pit latrines	A pit with a seat, in a shelter.		Basic enough for people to construct themselves.	Often badly built. Problem with flies and stench.	Dar-Es-Salaam, Tanzania.
Bucket sanitation systems.	A bucket is placed under a seat in a privy.			Problem with flies and stench. Bucket soons fills when many people use the system.	
VIP latrines.	Reinforced pit with concrete cover and seat. Air vent with screen and anti-mosquito baffle.		Easy to construct. Cheap. Hygienic	No good if ground is rocky or groundwater table is near suface.	Zimbabwe.
Aqua-privy with on-site disposal.	Waste enters a digester to be processed by bacteria. Liquid effluent soaks away.	**1**	Cheap. Easy to install.	Water tank needs frequent filling. Digester requires periodic emptying. Effluent can contaminate the surrounding ground.	India.
Septic tank.	As aqua-privy with on- site disposal, except that this is a full flush system on-site disposal.	**10-20**	Can be installed where there are no sewers.	Expensive to install. Reserved for large sites. Cost of emptying sludge disposal.	
Aqua-privy with solid-free sewer or simplified network.	Waste enters a digester to be processed by bacteria. Liquid effluent is evacuated by sewer pipe.	**1**	Small volume of water needed for flush. No soakway required.	Digester needs periodic emptying.	USA, Australia, Brazil.
Intermediate flush sanitation (with sewer).	Similar to a full flush system but uses less water. All waste goes to a sewer.	**3-6**	Full flush system is convenient. Use little water.	Needs to be designed and installed correctly.	
Full flush sanitation (with sewer).	Full flush system with on-site sewer to transfer waste to main sewer.	**10-20**	Most convenient system.	Most expensive system to construct. Uses the most water.	Developed cities.

4 Structure and alternatives for water systems

The following scheme is the result of extending discussions and communication with colleagues, and the result may certainly not be perfect. Anyhow, this structure covers the different technologies, demonstration-projects and ideas (which, of course, will usually touch more than just one of the elements defined in the scheme).

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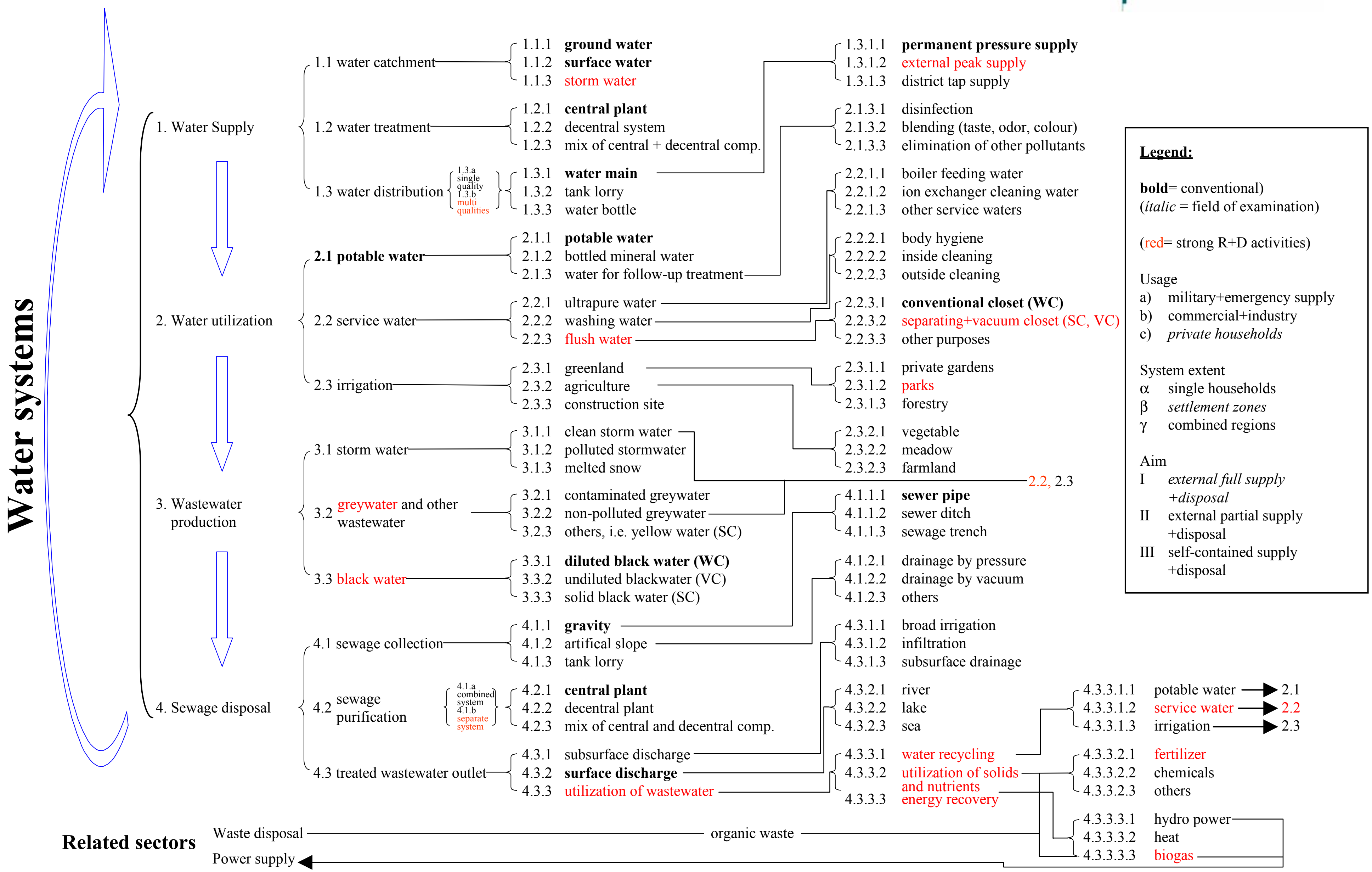


Figure 1

5 Researched projects

The following table is a comprehensive list of all important projects, which have been included in the survey.

Table 3: Investigated Projects concerning Alternative Water Systems

System	Class.No.	Annotation	Doc. No.	Country
WR-PW (Wastewater-Recycling for potable water)	4.3.3.1.1	Aquafin and IWVA plan to reuse WWTP effluent for potable purposes. Different technologies will be researched (microfiltration, RO, infiltration zones).	13	Belgium
WR-PW	4.3.3.1.1	Pilot plant in San Diego. Suspended in 1999.	17	USA
WR-PW	4.3.3.1.1	Pilot plant in Tampa Bay. Suspended in 1999.	18	USA
WR-PW	4.3.3.1.1	Pilot plant in Denver, 3,785 m^3/d	19	USA
self-sufficient building	4.3.3.1.1 1.1.3	Healthy House in Toronto. Totally self-sufficient. Potable water produced from storm water, passing limestone, sand filter, activated coal and UV disinfection.	41	Canada
WR-PW	4.3.3.1.1	Wastewater reuse in Windhoek.	29	Namibia
WR-PW	4.3.3.1.1	2 demonstration plants at Quakers Hill WWTP	28	Australia
GR (Greywater-Recycling)	4.3.3.1.2	Plant in Berlin.	1	Germany
GR	4.3.3.1.2	Hotel Arabella in Offenbach since 1996, 20 m^3/d.	52	Germany
GR	4.3.3.1.2	Pilot project "Haegewiesen" in Hannover. 4 different systems were tested.	50	Germany
WR (Wastewater-Recycling)	4.3.3.1.2	Toilet with water recycling using membrane technology, presented at WASSER BERLIN 2000.	53	Germany
GR	4.3.3.1.2	Millennium Dome in London, grey water for toilet flushing.	4	UK
GR	4.3.3.1.2	10 Environment Agency employees tested grey water systems in a two-year study.	5	UK
GR	4.3.3.1.2	Three Valleys Water Company and Crest Homes installed grey water systems in 8 houses in Shenley	6	UK
GR	4.3.3.1.2	Millennium House of Wilcon Homes	7	UK
GR	4.3.3.1.2	Grey water system installed in a student accommodation at the University of Oxford.	9	UK
GR	4.3.3.1.2	Grey water system at Linacre College, Oxford, installed by Anglian Water. Sand filter and hollow fibre membrane.	11	UK
GR	4.3.3.1.2	Grey water from a number of flats on the campus of Cranfield University is treated by a range of processes.	12	UK
GR	4.3.3.1.2	2 different biological systems were tested at Loughborough University.	31	UK
WR	4.3.3.1.2	Wastewater reuse at Fukuoka City. 6,300 m^3/d, 173 buildings	21	Japan
WR	4.3.3.1.2	Wastewater recycling in Tokyo. New buildings with more than 10000 m^2 have to use recycled water for toilet flushing.	22	Japan
WR	4.3.3.1.2	Wastewater reuse in Yokohama	23	Japan
WR	4.3.3.1.2	Wastewater reuse at "Ikebukuro Sunshine City", Tokyo.	38	Japan

System	Class.No.	Annotation	Doc. No.	Country
WR	4.3.3.1.2	The final plant in Bedok will provide 10,000 m³/d.	30	Singapore
GR	4.3.3.1.2	Pilot SBR-Reactor with microfiltration for grey water recycling.	37	Korea
WR	4.3.3.1.2	New development projects will be built in Mission Bay, Hunters Point and Treasure Island ("Article 22 of the San Francisco Public Works Code - Reclaimed Water Use")	20	USA
WR	4.3.3.1.2 4.3.3.1.3	Wastewater reuse in Grand Canyon Village.	36	USA
WR	4.3.3.1.2	Wastewater reuse in high-rise office buildings in Irvine, California.	34	USA
GR	4.3.3.1.2	At Casa del Aqua in Arizona different systems for grey water reuse were tested.	59	USA
self-sufficient building	4.3.3.1.2 1.1.2 1.1.3	Eagle Lake First Nation Healthy House Project.	62	Canada
GR	4.3.3.1.2	Grey water reuse in 8 households in Ottawa.	54	Canada
GR	4.3.3.1.2	Grey water recycling system for 20 housing units at North Vancouver, B. C.. Grey water is treated by a sand filter, activated coal and UV. After a period of testing the system, treated water will be used for toilet flushing, shower and washing.	55	Canada
WR	4.3.3.1.2	Wastewater reuse at Yellowknife.	56	Canada
WR	4.3.3.1.2 1.1.3	Wastewater reuse in Cape Dorset. System of the Healthy House in Toronto	57	Canada
WR	4.3.3.1.2	Wastewater reuse at office of Ministry of Social Services in Sooke, British Columbia (3,8 m³/d).	58	Canada
GR	4.3.3.1.2	Pilot plant for grey water reuse at Charles Sturt University Campus	24	Australia
GR	4.3.3.1.2	Study on 4 houses in Melbourne with grey water treatment (1993-95).	25	Australia
WR	4.3.3.1.2 4.3.3.1.3	Project in Rouse Hill starts 2000. After 5 years 100000 houses (8 ML/d) will be supplied with re-cycled water for toilet flushing and irrigation.	26	Australia
WR	4.3.3.1.2 4.3.3.1.3	Wastewater treated to a high standard using microfil-tration and RO used for toilet flushing and irrigation at the Sydney Olympics site Homebush Bay (2,000 m³/d)	27	Australia
WR	1.1.3 2.2.3.3 4.3.3.1.2	Sydney's sustainable house. Water supply by treated storm water.	39	Australia
GR	4.3.3.1.2	Grey water from 6 housing units is recycled at an old people's home at Palmyra. Disinfection with chlorine.	33	Australia
GR	4.3.3.1.2	Grey water is used for sinks and toilets at Technical University College of Kalmar.	32	Sweden
GR	4.3.3.1.2	Grey water recycling system for the UK`s BBC Television provided by Anglian Water.	64	UK
WR	4.3.3.1.2	In Jurong Industrial Estate in Singapore, 25,000 people are living in a 12-story apartment building, where treated wastewater is used for toilet flushing.	63	Singapore
Vacuum toilets/ biogas	4.3.3.2.1 5.2	Project in Freiburg. Fertiliser and biogas is produced from faeces, urine and organic waste.	3	Germany

System	Class.No.	Annotation	Doc. No.	Country
separation	4.3.3.2.1	100 housing units at the SolarCity Pichling will get separating toilets. Urine and solid wastes shall be used as fertiliser.	60	Austria
separation	4.3.3.2.1	Urine is collected separately at the museum of Mon and used as fertiliser.	42	Denmark
Vacuum toilets	4.3.3.2.1	Wastewater from vacuum toilets is mixed with lime-stone. At pH 12 all bacteria and viruses are killed and the mixture can be used as a fertiliser.	16	Sweden
separation	4.3.3.2.1	Ecovillage Björnsbyn, urine separation at 17 houses.	35	Sweden
separation	4.3.3.2.1	Hanaeus and Johannson report on 11 larger plants which were implemented before 1996.	61	Sweden
separation	4.3.3.2.1	House with 18 apartments at Norrköping. Urine and faeces are collected separately and used in agricul-ture.	43	Sweden
separation	4.3.3.2.1	Ecovillage Understenshöjden, 44 flats.	46	Sweden
vacuum toilets	4.1.2.2 4.3.3.2.1	At the Tegelviken school in Kvicksund black water is collected by a vacuum system and brought to a farm nearby, mixed with cow dung and composted. The product is used as fertiliser.	47	Sweden
separation	4.3.3.2.1	Lambertsmühle near Burscheid. Agricultural utilisation of urine.	49	Germany
separation	4.3.3.2.1	Ecovillage Toarp, 37 houses	14	Sweden
faeces + organic waste	5.1	"Waldquellesiedlung" in Bielefeld, settlement with 62 inhabitants.	48	Germany
faeces + organic waste	5.1	House "Ramshusene" with composting toilets. Composted Faeces and composted organic waste are mixed and used as fertiliser.	40	Denmark
vacuum toilets	5.1	House in Oslo. Black water collected by vacuum toilets is mixed with organic waste and brought to a farm nearby.	44	Norway
low flush toilets and biogas	5.2	Black water from low-volume toilets and organic waste are fermented to gain methane.	51	Sweden
GR	5.2 4.1.2.2	Ecovillage Flintenbreite near Lübeck. Faeces are col-lected by a vacuum-system and mixed with organic waste to produce biogas.	2	Germany
separation		3000 housing units in Sweden using separating toilets.	15	Sweden
composting toilets		The city of Tanum decided that from the year 2000 every new building has to use composting toilets.	45	Sweden
dry composting toilet, waterless urinals		Waterless urinals at four National Trust sites. Ultra low flush and waterless composting toilets in Gloucester and Purbeck.	8	UK
GR, composting toilets	1.1.3	3 Gledhow Valley Eco-Houses. Autonomous water systems without link to mains water supply or sewage outlet.	10	UK

6 Outstanding experiences

Selected from many, the following outstanding projects shall be described in short terms.

6.1 Rainwater Harvesting

It is quite interesting, that storm water utilisation has gained remarkable success especially in Germany, where more than enough natural water resources are available. The motivation of private house owners, to save water and use their local resources, was one of the driving factors for this.

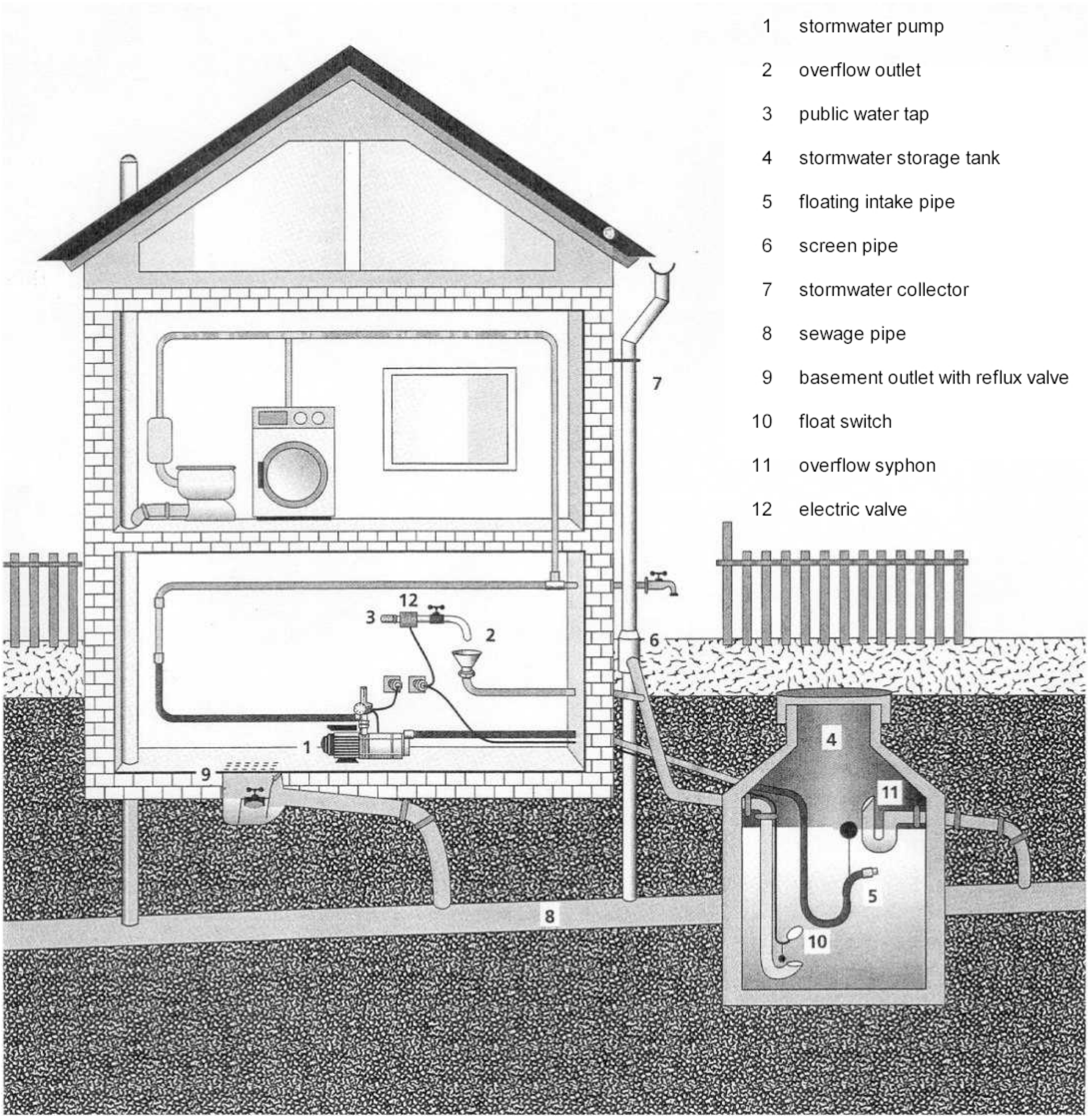


Figure 2: Inhouse Facilities for Rainwater Harvesting
(Source: ArGe Verbraucherverbände, 1995, revised)

6.2 Grey Water Recycling

The separated collection of grey waters (excluding black waters = faecal sewage from toilets) is certainly one of the most important methods to disburden the capacities of the centralised systems. It seems understandable that this had to be done preferably in very densely populated areas with sufficient economical standard. The project of Ohtemachi House in Tokyo is one of the large facilities for decentralised grey water recycling.

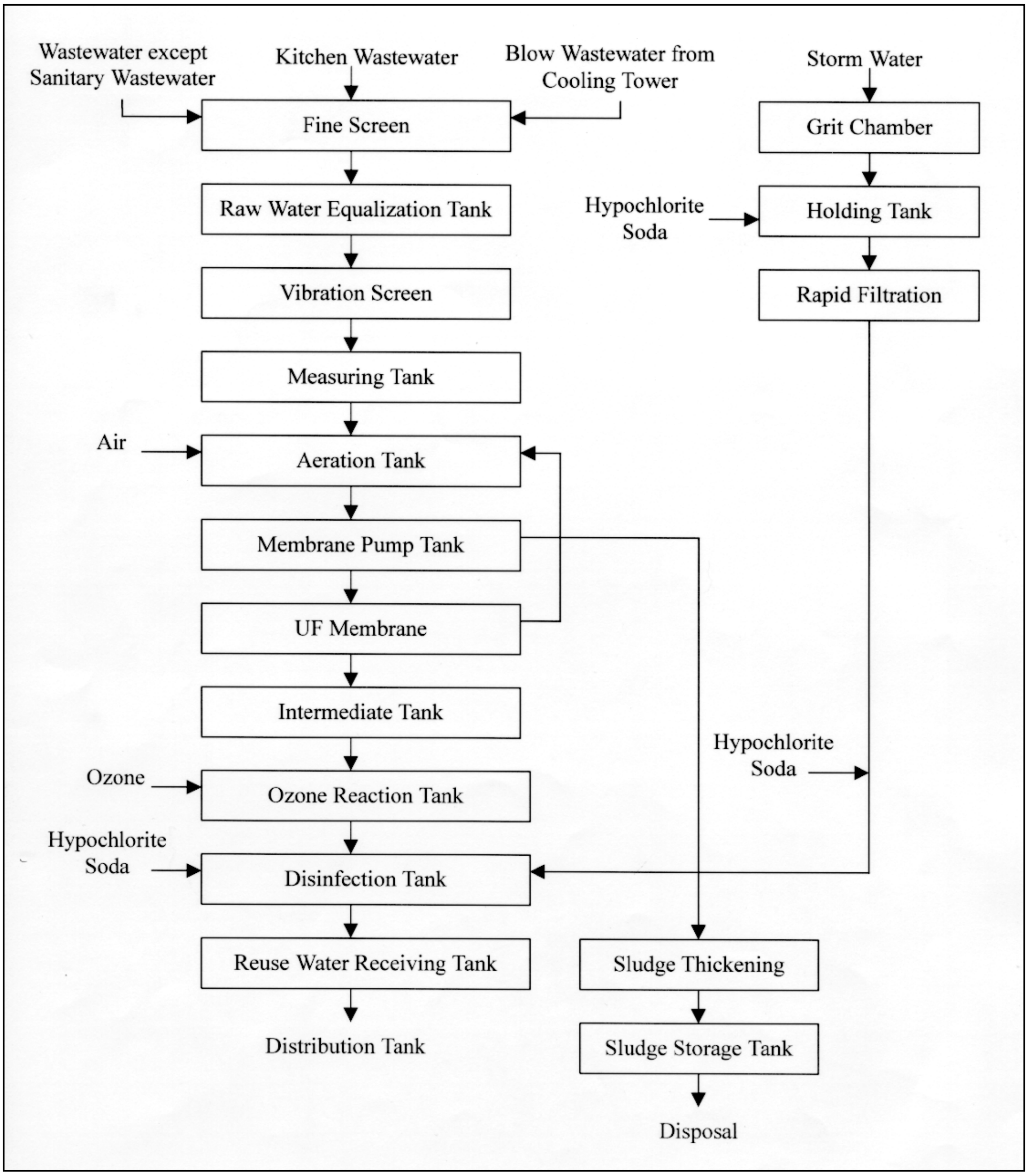


Figure 3: Flow Sheet of the Ohtemachi Grey Water Purification Plant
(Nishihara Environmental Sanitation Research, 2000)

6.3 Ecological Sanitation

The idea, to collect, treat and utilise waste waters separately has been realised to high practical standards in several cases.[1] The black water can be digested (biogas production), and the remaining sludge contains nutrients for fertilisation, grey waters can be purified in a reed bed filter, and the effluent used for irrigation. Sometimes, separation toilets are used so that "yellow water" with rich ammonia content can be harvested.

6.4 Full Water Recycling

"Full" water recycling means that waste waters are purified to a standard that they can be re-utilised as drinking water. This has been done in Namibia and tried in several locations with severe water shortages in the USA. Technically, the full recycling process is possible. Anyhow, there are general reservations because of unknown and undetected toxic agents or microbiological contaminants.

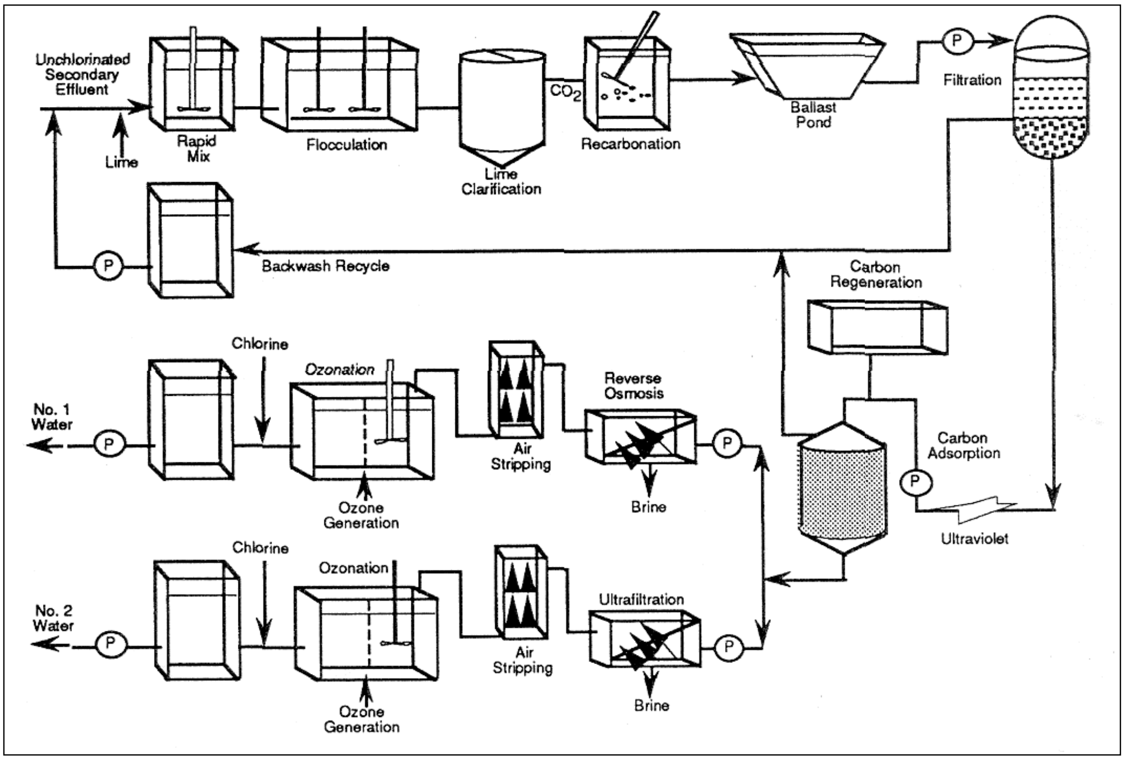


Figure 4: Denver Potable Reuse Demonstration Treatment Plant Processes (EPA, 1992)

[1] Deutsche Gesellschaft für technische Zusammenarbeit (GTZ):
ecosan - closing the loop in wastewater management and sanitation
Proceedings of the International Symposium, 30 - 31 October 2000, Bonn, Germany
http://www.gtz.de/ecosan

7 Economic aspects

As it was found that in many studies about alternative water systems the wrong method for cost evaluation was applied, and that basic phenomenons from the water sector were not fully respected, the following explanations are given.

7.1 Fixed Costs

To save water and to save costs may be two different stories. Wherever water systems have been built to full capacities, the reduction of water sold will lead to higher costs per m³ of water consumption. The following figure shows the data for one example from Germany.

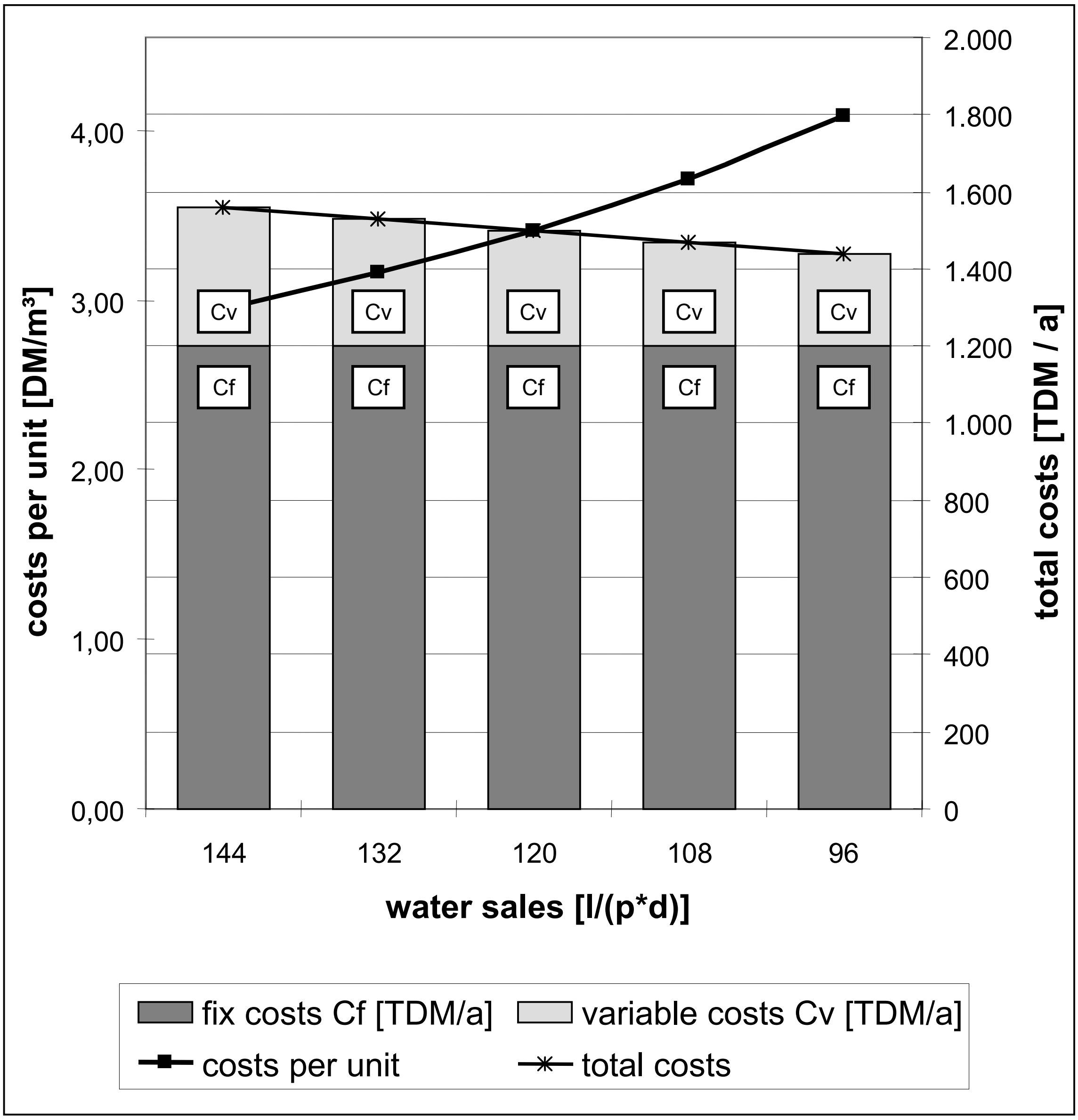
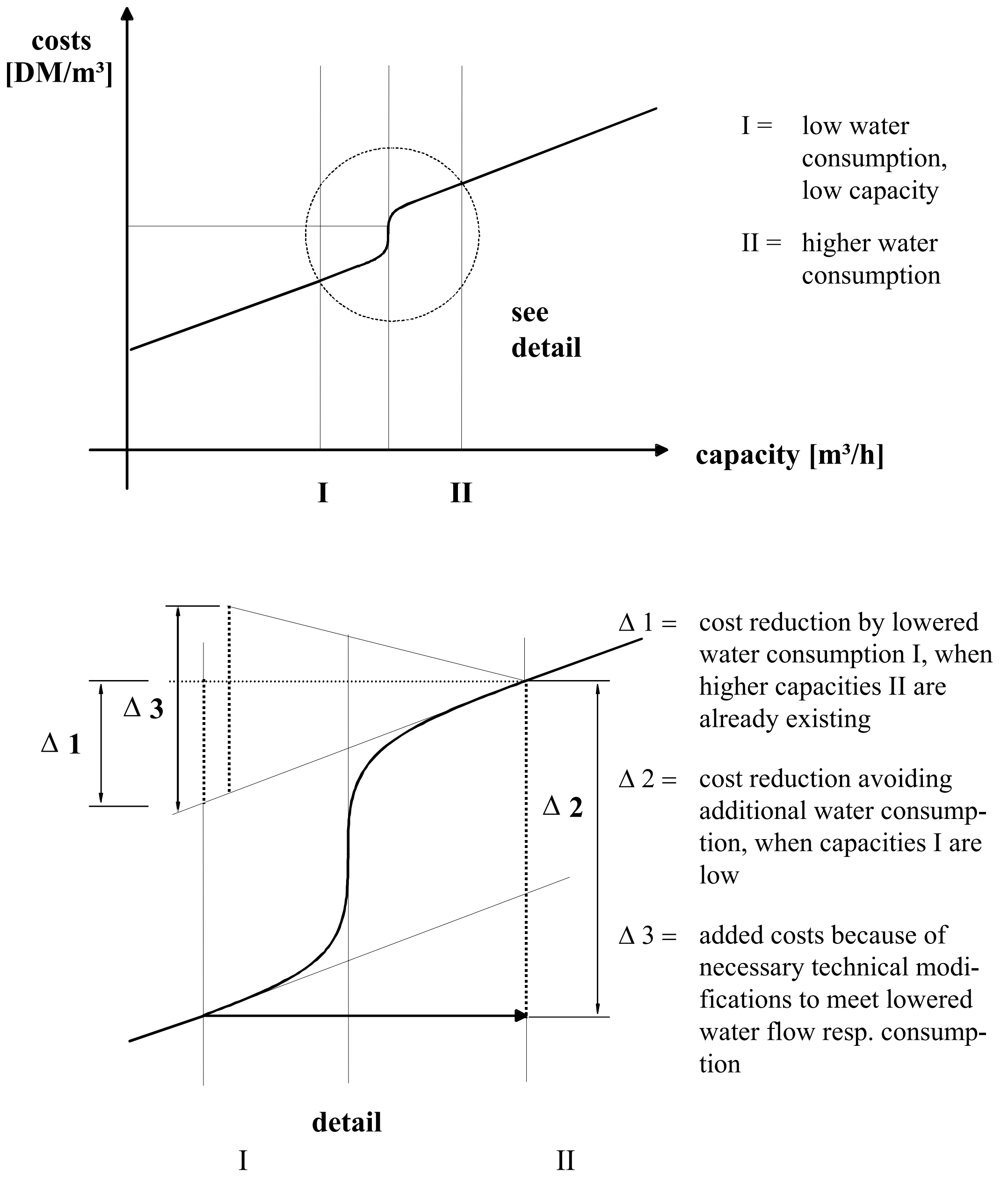


Figure 5: Waste Water Costs Per Unit with Changing Water Consumption
(Rudolph, K.-U., Antoni, M., 1998)

7.2 Threshold Costs

This leads to the fact that costs are "jumping", whenever the capacity of an existing water system has to be enlarged. On the other hand, costs are not decreasing linear, when water consumption is reduced after these capacities had already been built.



Cost difference versus change of water consumption Δ

Figure 6: Cost Tresholds
(Rudolph, K.-U., Antoni, M., 1998)

This phenomenon is very important. If the water utility succeeds to make customers save water, before new capacities have to be built, this may save a remarkable amount of money (Δ 2). If consumers save water, after new plants with full capacity have already been invested, the costs will remain higher (Δ 1), because the fixed costs CAPEX have already been spent.

In some cases, existing networks and plants tend to run into technical difficulties, when the water volume is decreasing below a certain minimum. Whenever the retention time of water in storage tanks, networks etc. is too long, additional disinfection measures etc. may be needed.

After the re-unification with East Germany and the huge investment spent for the sake of the water environment there, cost covering water tariffs had to be introduced. The consumption dropped from nearly 400 litres per capita and day to sometimes 70 litres per capita and day! In one case, a water supply pipe had to be equipped with an inliner, to reduce the diameter and gain a better flush rate for the sake of fresh water supply. In such cases, the decrease of water consumption may result in even higher costs (Δ 3).

7.3 CAPEX and OPEX

It makes a big difference, whether CAPEX is defined from the view of the customer, the view of a water utility or the view of national economy.

The water customer will look at the official water tariffs and sewerage charges (as far as these are really billed and collected, which is not always the case in some developing countries).

The water utility will have to check, whether capacities are sufficient or not, and they will have to calculate their delta-costs (Δ), as explained in figure 6.

From the view of national economy, a long-term calculation has to be done, and subsidies and taxes have to be reduced ("transfer payments", from one pocket of members of the national economy to the other pocket).

It may be well understandable that the results of any project evaluation are much different depending on the view, which is implemented in the evaluation.

This is similar for OPEX. Especially the costs for labour have to be defined, whether they result from;

- professional labour
  calculated with the usual cost units, depending on the situation in the area of the project,

- unemployed labour
  which is to be considered much cheaper, at least under national economy view;
  whenever lower rates of unemployment improve the political stability and reduce the rates of criminal actions in the region, it might be justified to talk about "labour benefits" instead of "labour costs",

- work for fun
  which is very important for wealthy house owners as existing in Germany, who are happy to construct their own rainwater harvesting systems etc.;
  it would be wrong to calculate their working time at professional cost units.

8 Application of AWS

The most important types of alternative water systems (AWS) may be classified for the different cases of application, which seem to be the following.

8.1 AWS for Urban Areas (High Population Density)

a) Low Cost System: Distribution of bottled drinking water

One famous example is Mexico City. Water resources are not generally scarce, but inefficient protection of natural water sources leads to deficits. Water supply does not work because of technical deficits, caused by institutional problems. The water from the central supply systems does, very often, not meet the hygienic standards. Most of the customers buy drinking water from bottles (2 and 5 gallons), and public supply water is used for other purposes.

Figure 7: Water Supply with Bottled Water in Peru
(Photo: GTZ PROAGUA, 2001)

b) High Tech System: Water Recycling

Water supply and waste water disposal are centralised. A part of the waste water is recycled, and here three different cases are existing:

- grey water recycling for large buildings
  example: Ohtemachi House, Tokyo (figure 3)
  with an in-house system for the collection, the treatment and re-distribution of grey water (including collected storm waters) to be used for toilet flushing,

- waste water recycling for selected settlements
  example: Chiba, Tokyo
  the sewage plant is equipped with advanced treatment, and a part of the effluent is additionally purified to be utilised for toilet flushing, for greenland irrigation and as supply water for central heating and central air-condition of a new business quarter.

  The costs for storage tanks and distribution pipe systems are quite significant, as can be seen from figure 8.

Figure 8: Chiba Service Water System
(Photo: Rudolph, 2001)

- full water recycling
  with re-utilisation of purified waste water as drinking water (see figure 4).

  Well-known examples are the plant system in Windhoek, Namibia, operating since 1969, and the pilot projects in Denver, San Diego and Tampa Bay, USA.

8.2 AWS for Small Towns (Medium Population Density)

a) Low Cost System: Public Water Taps

For slums or very low income quarters in developing countries, it is necessary to achieve minimum hygienic standards without exceeding the affordable budget. Public standpipes, serving a group of houses nearby, are one solution, as shown in figure 9. Latrines and grey water collection ditches have to be sufficient for the waste water disposal.

Figure 9: Tap supply in Peru
(Photo: GTZ PROAGUA, 2001)

b) Separation Toilet

Separation toilet makes it possible to separately collect "black waters" and "yellow waters". "Black waters" can be used in an anaerobic bio-reactor, and the bio-gas produced can be used for heating and the remaining dry solids as fertiliser. Grey waters can be treated separately, e.g. in a reed bed filter, and the effluent can be used for irrigation.

A full system with vacuum pipes for black water collection is demonstrated in the German "Flintenbreite", near Lübeck, where a vacuum system for waste water collection is installed.

Figure 10: Separation Toilets
(Source: www.roevac.de)

c) In-house utilisation of storm water and grey water recycling

Rain water harvesting facilities are installed in many German houses under "do-it-yourself"-practice. The storm water (collected from the house roofs) is stored in storm water tanks, mechanically filtered and (together with purified grey waters) used for toilet flushing, sometimes for the washing machine and other purposes.

8.3 AWS for Rural Areas and Outside Locations (Very Low Population Density)

We find many technically different concepts, dedicated to rural areas etc., of which the following seems to be important:

a) Small units for water supply and waste water disposal
(water and sewage plants for 1 - 10 population equivalents)

b) Small multi-utility systems

- waste water disposal and water supply
  (grey water recycling),

- waster water disposal and solid waste management
  (e.g. combined digestion of black water and organic wastes),

- water supply and power supply
  (e.g. combined power plant with generation of heat and electricity, linked to a seawater desalination plant),

- waste water disposal and power supply
  (e.g. digestion of black waters and production of bio-gas for power generation),

- multi-combinations between the ones already mentioned.

8.4 AWS under Short Resources

a) Scarce Water Resources
(arid regions)

Often, the *water down-cycling* is recommended, tested and successfully realised. It is established in many countries like Israel, Jordan, in African countries or in California/USA etc., where fully and advanced treated waste water is used for irrigation and watering of green parks and agriculture.

Figure 11: Michelson Water Reclamation Plant
(Irvine Ranch Water District, 2001)

b) Sensitive Waters

If it is not possible to get rid of the waste water, because there is no river or sea nearby, which could "swallow" waste water, then it may become very expensive to get rid of it. Especially for industry it might be cheaper to reduce water consumption, and thus reduce the quantity of waste water. This has been done to a large extent e.g. in the industry of Germany, when production processes were re-engineered and a large number of water recycling plants has been installed.

8.5 AWS under Extreme Site Conditions

a) Technical Requirements

It is clear that for "mobile units", like ships, trains etc., specific alternative water systems are needed (very often vacuum systems for waste water and thermal processing or membrane technology for the reutilization of grey water).

Sometimes, extreme site conditions force the water consumer to find his special solution.

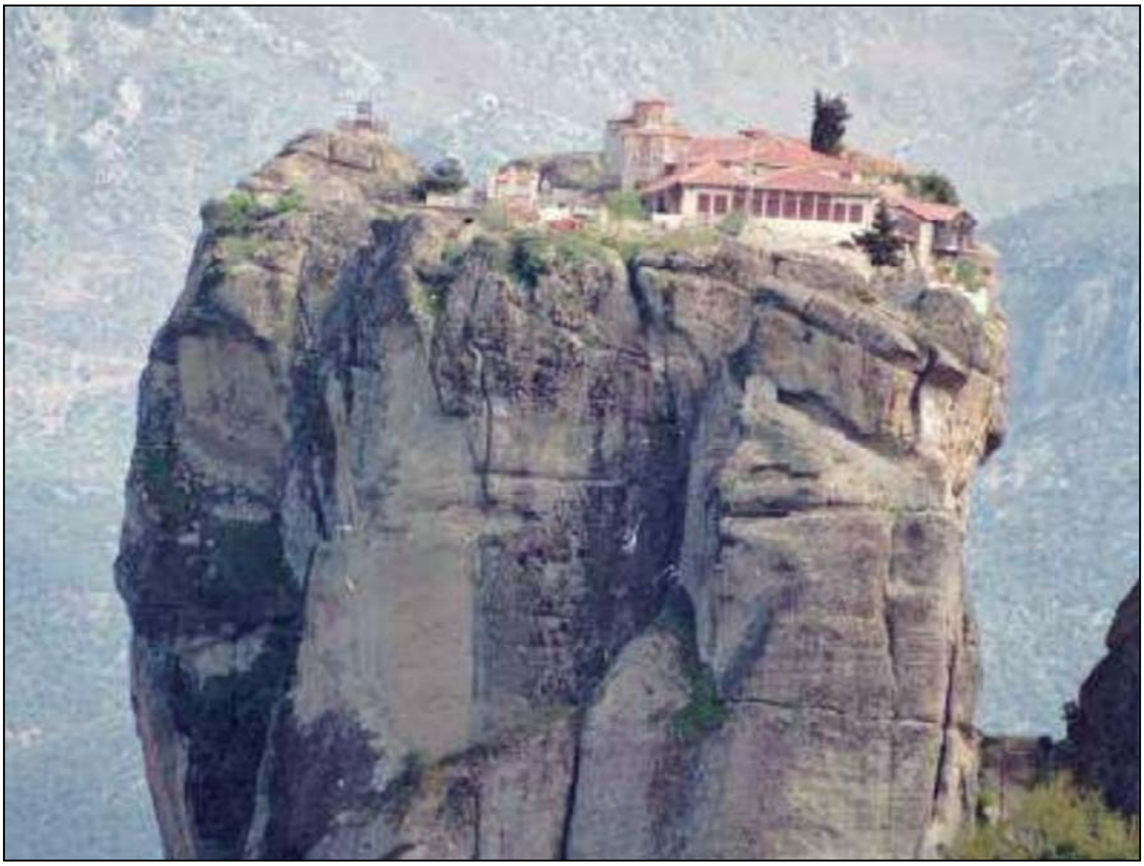


Figure 12: Meteora; Monastery of Holy Trinity, Greece
(EU FAIR Project)

b) Political Instabilities

One should not expect that public supply will work properly under poor institutional conditions or political instabilities. Therefore, industrial estates, hotels, business houses and wealthy private facilities have to run their own, independent systems (e.g. in cities like Nairobi, Tirana, Kathmandu and others).

c) Restricted willingness to pay

In very low income regions it is not possible to find enough customers, who are able or willing to pay for the full water and sewage services. Alternative water systems with low cost standards have to be applied, which will hopefully reach a minimum hygienic standard for the sake of public health.

In the opposite, customers in rich countries may tend to pay much more for alternative water systems, because they want their own independent plant or the ecological "better" solution with lower water consumption (as this is the case with quite a number of German customers, not only "nature-people" or such).

9 Final remark

During the international survey about alternative water systems, a large number and rich variety of different approaches, technologies and organisational concepts was collected.

There is a growing demand for systems, which can work with *lower budget* and *lower water consumption* than the conventional systems, which are still the solution of best comfort and reliability appropriate for settlements in the developed world, whenever enough water and money is available.

Membrane modules, computer control system and tele-metering, separated collection of different waste waters and dual water supply on in-house level with *grey water* recycling, and the combination of water, waste water, solid waste and power supply in *multi-utilities* (especially on decentralised level) seem to be the most important technologies for the future development.

The success in research and development will be driven mainly by projects, which focus a systematic and *integrated approach*. The development of technical components seems to be of minor importance in that context - many of them are already existing.

It should not be forgotten that new technologies in the energy sector (*fuel cell*) may open up totally new opportunities for the design of water systems. Anyhow, the toilet with integrated waste water incineration and fresh water distillation seems to be an option for the far future, which one cannot rely on to solve the problems of today.

What is needed, are pragmatic solutions in *demonstration facilities*, which can prove that they are economically reasonable, ecologically sustainable and (last not least) technically reliable under normal working conditions.

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18. Abstract

"Alternative Water Systems" (AWS) is not a new topic and has been dealt with for decades. Of growing importance are membrane technologies and water saving installations. Modifications of the conventional water system (= centralised pressurised pipe supply with disposal via gravity sewers), leading to semi-centralised or fully decentralised schemes, often focused on triple wastewater collection and dual water supply with grey water recycling, rainwater harvesting and the utilisation of sewage-fertilisers and biogas production - up to multi utility schemes (water + wastewater + solid waste + power supply).

The focus of this international research, funded by the BMBF, was to give an overview which AWS methods, concepts and projects are already existing resp. under development world-wide.

Australia, Germany, Japan and Canada are some of the countries, where many AWS activities and high-tech innovations were found. Low-tech concepts, able to serve the poor, are emerging mainly in developing countries and rural areas.

In future, it is necessary to further improve and demonstrate the economic sustainability and technical reliability of holistic AWS concepts.

19. Keywords

Alternative Water Systems, EcoSan, decentralised water system, grey water recycling, service water utilisation, wastewater recycling, nutrient recovery, membrane technology