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Industrial waste water treatment in Dar es Salaam, the Vingunguti waste stabilization ponds

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Final report, May 1996.

Industrial Waste Water Treatment in Dar es Salaam, the Vingunguti Waste Stabilization Ponds.

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Abstract

This investigation focuses on the performance of the Vingunguti waste stabilization ponds. The waste water characteristics of the influent are estimated with the Rapid Assessment method. With these estimates a reassessment of the waste stabilization pond design is made, according to the Waste Stabilization Pond Design Manual for Eastern Africa, showing that the ponds are overloaded. Waste audits in selected industry were done to identify options for waste water prevention. The institutional analysis indicates that the present institutional setup is a major constraint to execute waste water treatment services effectively. Strengthening of institutions and support towards industry is needed to make the waste stabilization pond technology appropriate for Tanzania.

Foreword

This investigation on industrial waste water treatment in Dar es Salaam was carried out between April and November 1996. In Tanzania my supervisor Michael Yhdego of Envconsult has been an inspiring support. Furthermore many people at many different institutions and industries helped me to collect information. I want to thank all of them, especially Kayombo at the Water Resource Institute/University of Dar es Salaam for all the stories he told me, Lyatuu and Mrema and their colleagues at DSD, Kirango and Chale Simon and their colleagues at DSSD, F.Z. Njau the Principal Engineer at the Ministry of Water Energy and Minerals, Msuka at Howard & Humpreys, all the employees of Zahra Bottlers and Coastal Oil who welcomed us friendly every time, M.A. Mgunda the Managing Director of Tanzania Cyclebells Manufacturers Ltd who took the time to tell us all about electroplating, and Chuwa the Engineer at the Tazara Workshop. I also want to thank all my friends in Tanzania for making our stay an unforgettable wonderful experience, especially Frank who is my most special friend everywhere and always - I will never forget Selous - Viboko - the smile on your face.

In the Netherlands my three supervisors of the Eindhoven University of Technology taught me how to do the investigation scientifically correct, from proposal up to reporting in correct English. Therefore I am very thankful to Lex Lemmens who came to visit me twice in Dar es Salaam and who corrected and discussed my report several times. I am also very thankful to Prof. ir. S.P.P. Ottengraf for finding time to correct and discuss my report, and also to Prof. dr. A. Szirmai for his comments.

Today, as you listen to this song, another 349,000 children were born into this world .... they break like waves of hunger and desire upon these eroded shores .... carrying the curses of history and a history yet unwritten................

(New Model Army - Love of Hopeless Causes)

Contents

Summary

Most waste water in Tanzania is discharged untreated. This results in serious health and environmental problems. Therefore an increase of treatment facilities is needed in the near future. Presently, the most common waste water treatment technology used in Tanzania is the waste stabilization pond technology. The poor performance of the existing waste stabilization ponds raised the question whether this technology could be made appropriate for waste water treatment in Tanzania.

According to the Rapid Assessment method of the World Health Organization the amount of waste water flowing to the Vingunguti waste stabilization ponds is estimated at $1.6*10^5$ m^3/year with an estimated BOD of 160 t/year. An unexpected large contribution is made by the domestic users, responsible for more than 50% of the waste water flow. But the Rapid Assessment method overestimates the domestic water use, as little water is supplied. Other large waste water volumes are produced in the Car Maintenance sector (11%), the Textile sector (10%), the Metal Product Manufacturers (10%), and the Food and Beverage sector (8%). The BOD originates for 66% from the vegetable oil industry, 17% from domestic use, and 8% from the Textile sector. The contribution of the oil industry is overestimated by the Rapid Assessment as this method assumes that seeds are used as raw material which is not the case.

The organic loading of the ponds is calculated to be approximately 460 kg/ha/day under present conditions. If industries would produce according to their 1995 targets the organic loading would be approximately 940 kg/ha/day. Furthermore, the calculations show that the design criteria of an effluent BOD < 5 g/m^3, can not be achieved under present circumstances. However, 30 g/m^3 BOD is permitted by the Tanzanian Effluent Standard for direct discharge. The waste stabilization pond effluent would exceed this standard only if the industries increase their production above their 1995 targets. Such an increase in future is likely as most industries are producing at low capacity, and new industrial sewer connections might be approved. Waste Audits in selected industries indicated that a limited decrease in waste water flow to the ponds can be achieved by waste water prevention in industries.

The present performance of the waste stabilization pond is below expectations. Little room for expansion is available at the waste stabilization pond site. However it might be possible to improve the performance significantly by implementing relatively simple measures, like improved in- and outlets to prevent short circuiting and desludging. Furthermore, influent control could prevent the inflow of compounds like zinc, lead, copper, chromium, cyanide and oil. These compounds inhibit the biological treatment process and thus deteriorate the performance of the waste stabilization pond system. Information on waste water characteristics and the performance of existing treatment facilities is needed to assure better design in the future. As such the waste stabilization pond technology will be appropriate for Tanzania if institutional strengthening leads to better operation and maintenance as well as better control and enforcement of the existing environmental laws.

1 Introduction

Large amounts of untreated waste water are polluting the environments of many developing countries. Due to growing population, expanding cities and developing economies the need for appropriate waste water treatment systems is likely to increase substantially in coming decades. Today the application of Waste Stabilization Ponds (WSP) is common to treat both domestic and industrial waste water in developing countries (see appendix 1). However many waste stabilization pond systems are not performing as well as they should. In Dar es Salaam eight systems are presently operating. According to various studies the performance of these systems is poor (Haskoning 1989, Mgeyekwa 1990, Yhdego, 1992, Proceedings 1994).

Therefore the aim of this investigation is to find out whether the waste stabilization pond technology is appropriate for waste water treatment in Dar es Salaam.

1.1 Sustainable development

Addressing waste water problems in Tanzania is an essential contribution to achieve sustainable development. For many people in Tanzania water supply, sanitation and solid wastes are the most important of all environmental problems. An estimated 80% of all diseases and one third of all deaths in developing countries are caused by the consumption of contaminated water, and on average as much as one tenth of each persons productive time is lost because of water-related diseases (World Bank, 1992).

Untreated, or inadequately treated, sewage disposal is the major source of water pollution. This effect is enhanced by uncontrolled waste disposal. When decomposition of pollutants lowers the amount of oxygen dissolved in the water, the effects on aquatic life, such as fish, may be economically important. Sewage water, agro-industrial waste water and nutrient run-off in agriculture areas with intensive fertilizer use cause these problems.

Industry, mining and the use of agricultural chemicals contaminate water with toxic chemicals which can be hard to remove with standard drinking water purification techniques. The pollutants may accumulate in shellfish and fish, which may be eaten by people who depend on fish for proteins.

As surface water near towns and cities becomes increasingly polluted and costly to purify, public water utilities and other urban water users have turned to ground water as potential source of a cheaper and safer supply. Monitoring of ground water for contamination has lagged behind monitoring of surface water, but this is beginning to change because in many places ground water, too, is becoming polluted. It is often more important to prevent contamination of ground water than of surface water. Aquifers do not have the self-cleansing capacity of rivers and, once polluted, are difficult and costly to clean.

The international community has recognized these problems and explicitly addressed them at UNCED in Rio de Janeiro in 1992. The resulting agenda 21, the United Nations programme for action for sustainable development, calls for the following activities in relation to water pollution:

- Application of the '*polluter pays*' principle where appropriate, to all kinds of sources, including on-site and off-site sanitation;
- Promotion of the construction of *treatment facilities for domestic sewage and industrial effluent* and the development of appropriate technologies, taking into account sound traditional and indigenous practices;
- Establishment of *standards for the discharge of effluent* and for receiving waters;
- Introduction of the precautionary approach in water quality management, when appropriate, with a *focus on pollution minimization and prevention* through use of new technologies, product and process change, pollution reduction at source and effluent reuse, recycling and recovery, treatment and environmentally safe disposal;
- Mandatory *environmental impact assessment* of all major water resource development projects potentially impairing water quality and aquatic ecosystems, combined with the delineation of appropriate remedial measures and a strengthened control of new industrial installations, solid waste landfills and infrastructure development projects;
- Use of *risk assessment and risk management* in reaching decisions in this area and assuring compliance with those decisions;
- Identification and *application of best environmental practices* at reasonable cost to avoid diffuse pollution, namely, through a limited, rational and planned use of nitrogenous fertilizers and other agrochemicals in agricultural practices;
- Encouragement and promotion of *the use of adequately treated and purified waste waters* in agriculture, aquaculture, industry and other sectors.

These principles indicate the need for the development of insights and methods to address industrial waste water in densely populated area's like Dar es Salaam in Tanzania.

1.2 Waste water in Dar es Salaam

The final destination of waste water produced in Dar es Salaam is the Indian Ocean. In former days all the waste water was discharged untreated to the Indian Ocean. The waste water was transported through a sea outfall, river, or by vacuum tanker. During the mid-1960s and the early 1970s, waste stabilization ponds (WSP) were constructed to treat wastes from urban residential areas, industries, and public institutions. Presently eight WSP-systems can be found in Dar es Salaam (Proceedings, 1994).

An estimated amount of $22*10^5$ m^3 of waste water is flowing to the WSP-systems yearly, with a BOD-load of 10^3 ton per year (for explanation on the term BOD see appendix 4). Industries and institutions are responsible for 60% of this BOD-load while only 21% of the sewerage-connected industries and institutions discharge on a WSP-system. The waste water of the other 79% of industries and institutions connected to the sewer is discharged to the Indian Ocean without any treatment. Note that 75% of the industry and institutions are not connected to the sewer and discharge their waste water almost always without treatment to the surface waters (Haskoning, 1989).

To reach sustainable development in Tanzania, an enormous increase in waste water treatment facilities is needed in the near future. Therefore it is now very important to identify an appropriate waste water treatment technology for Tanzania. This investigation on the appropriateness of the technology presently used could be a first step towards sustainable handling of waste water in Tanzania.

1.3 Waste water treatment in Tanzania

A waste water treatment system in Tanzania has to cope with the following conditions:

Costs:
Tanzania cannot afford to spend large amounts of money on waste water treatment. The investment and operation and maintenance cost should be low.

Operation:
The system should be simple to operate since measurements and laboratory equipment are not general available, power breaks occur regular, and import of spare parts will be a problem.

Shock loads:
As both electricity and water are supplied insufficient and irregular, a waste water treatment system will have to endure pollution shock loads.

Pathogenic organisms:
For sewage treatment systems which treat domestic wastes the removal of pathogenic organisms is an important criteria.

The waste stabilization pond technology has been chosen for sewerage waste water treatment in Tanzania after consideration in the Sewerage Master plan (see box: 1). This biological treatment system has relatively low construction and operation cost. The system is easy to operate and is very effective in removing pathogenic organisms. The main disadvantage is the need for a relatively large land. The only alternatives operative in Tanzania are the tickling filters in Moshi and the direct discharge through sea outfalls.

Conventional Activated Sludge:
Primary treated sewage is aerated in aeration tanks. A high concentration of bacteria and other organisms is maintained in the aeration tank by returning the sludge settled out from the aeration tank contents. This settling is achieved in tanks called secondary settlement tanks and the sludge withdrawn from the bottom is known as activated sludge.
Main advantages: needs a smaller land area than most other processes; good quality effluent of BOD and SS.
Main disadvantages: need for secure process control and laboratory facilities; sensitive to changes in influent; high operational and maintenance costs.

Extended Aeration:
Based on the same principals as conventional activated sludge, with a prolonged period of aeration to be able to treat unsettled sewage.
Main advantages: elimination of primary sedimentation and separate sludge digestion; good ability to accept shock pollution loads; relatively easy to operate and maintain; good quality effluent of BOD and SS; relatively small amount of sludge produced.
Main disadvantages: larger land area needed than activated sludge; power consumption relatively high; need of relatively expensive tanks.

Oxidation Ditch:
A modification of the extended aeration process with longer periods of aeration in large continuous lined ditches.
Main advantages: simple to construct; elimination of primary sedimentation and separate sludge digestion; good ability to accept shock loads; relatively easy to operate; relatively small amount of sludge produced.
Main disadvantages: larger landarea needed than activated sludge, relatively large power consumption.

Biological Percolating Filtration:
Sewage passes through filter beds in which the media becomes covered with an active film containing bacteria, protozoa, fungi and other flora and fauna which aerobically stabilises the settled sewage.
Main advantages: good shock load capabilities; simple operation and maintenance; low power consumption; good effluent quality for BOD ans SS.
Main disadvantages: relatively large land area required; construction costs relatively high.

Rotating Biological Contactor:
A dynamic biological filter consisting of a number of fine mesh covered circular discs, slowly rotating on horizontal axis. A film of aerobic bacteria builds up on the discs and provides the biological treatment.
Main advantages: operation and control is simple; relatively low power costs; relatively small land area needed.
Main disadvantages: need for primary sedimentation and sludge digestion facilities; relatively new process has not been proven in operation under tropical conditions.

Waste Stabilisation Ponds system:
A series of large ponds in which the waste water is retained for a long period. Purification is effected by the symbioses of algae and bacteria in the presence of sunlight and air. Organic constituents of the pond are converted to a more stable sludge which settles on the bottom of the pond.
Main advantages: simple construction; low running costs; easy to operate and maintain; removal of pathogenic organisms is very good.
Main disadvantages: large land area is required; coloured algae laden effluent.

Box 1: Comparison of sewerage treatment systems (Ministry of Land, 1980).

The poor performance of the waste stabilization pond systems in Tanzania indicates that the technology is either not adapted or not appropriate. Literature states the following reasons for poor performance:

Design:
Standard design formulas were adopted without considering local environmental factors. The ponds were designed by overseas engineering firms based on the firm's experiences in similar projects, but not necessarily in similar climates (Yhdego, 1992). While in colder climates BOD is the most important design parameter in warmer climates faecal coliform bacteria removal is most important. Activated sludge plants may achieve a 99% removal of faecal coliform bacteria. This is only a reduction of for instance 10^8 per 100 ml to 10^6 per 100 ml while a waste stabilization pond system can, if properly designed, easily reduce faecal coliform numbers to $< 10^3$ per 100 ml (WHO guideline value for unrestricted irrigation; Mara, 1992).

A problem when designing ponds in Tanzania is the lack of reliable data leading to over- or under-dimensioning of ponds. Important data like the exact number of people that will be connected is unknown, water consumption is not measured except for very large consumers, water demand is generally greater than supply, and the strength of sewage in terms of biological oxygen demand (BOD) is unknown (Proceedings, 1994).

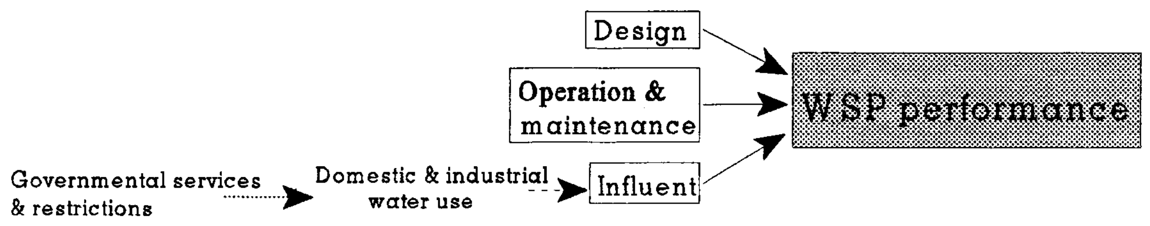
Maintenance:
The lack of maintenance and sludge removal, due to scarcity of funds and skilled operational supervision, has adversely affected the ponds performance and turned them into breeding sites for mosquitos.

1.4 Set-up of investigation

The waste stabilization pond technology is the most commonly used waste water treatment technology in Tanzania. In theory the technology is appropriate for developing countries. However the performance of the existing waste stabilization pond systems in Tanzania is poor. Therefore this investigation aims to find out whether the waste stabilization pond technology can be made appropriate for waste water treatment in Tanzania.

Appropriate technology is considered to be technology that is compatible with or readily adaptable to the natural, economic, technical and social environment, and that offers a possibility for further development.

Closer investigation of pond performance is necessary. The performance of an existing waste stabilization pond system will be the focus of this investigation. Performance depends on the design, operation and maintenance, and on the waste water entering the system. There are different design methods for waste stabilisation pond systems, some specially adapted to the East African situation. Operation and maintenance is in hands of governmental institutions. The amount and composition of the influent depends on the domestic and industrial water users that discharge to the ponds. These water users depend on the services supplied by governmental institutions and they are restricted by legislation.



Box 2: Theoretical model.

The Vingunguti WSP-system was chosen for this investigation because this system receives a significant amount of industrial waste water from different industries. There are other WSP-systems in Dar es Salaam which receive industrial waste water but it was said that either the waste stabilization pond system or the industry producing waste water was not operational.

The WSP-system was approached as a sewerage watershed. The water was followed upstream to the industries and through important industrial processes.

The actors in the investigation are the responsible institutions and the connected industries. The important institutions were visited, additional information comes from literature. All industries connected to the sewer leading to Vingunguti waste stabilization ponds were visited and asked to fill in a questionnaire. Since little information on waste water characteristics was available from both institutions and industries the Rapid Assessment method of the World Health Organization was used to make an estimate. The most important industries have been further examined using the waste-audit method by the UNIDO.

2 Methodology

The 'up-stream-approach' used in this investigation is a combination of three methods:

1) As no information is available on waste water characteristics like biological oxygen demand (BOD) the Rapid Assessment method is used to make an estimate. Information on waste water volumes is available from industries. These values are compared with the waste water volumes calculated with the Rapid Assessment.
2) One of the reasons for the poor performance of waste stabilization pond systems in Tanzania is said to be the use of standard design formula's. The Waste Stabilization Ponds Design Manual for Eastern Africa describes a design method adapted to the local situation. Therefore the waste stabilization pond design will be recalculated using this method and the results of the Rapid Assessment.
3) To unburden the waste stabilization pond system and to spare scares resources the UNIDO/UNEP Waste Audit method is used to identify waste water prevention options.

2.1 Rapid Assessment of industrial water pollution (WHO 1982, Economopoulos 1993)

The Rapid Assessment procedure described by the World Health Organization (WHO) is a preliminary assessment only. The waste water characteristics are estimated by multiplying production quantities with pollution factors. The advantage of the method is that information needed is readily available. As disadvantage the results of the assessment are not very accurate due to generalized pollution factors.

This method was chosen because little information was available concerning the characteristics of the waste water discharged by the industries connected to the waste stabilization pond system. Waste water characteristics are measured sporadic at the waste stabilization ponds. The registration of sewerage connections is far from complete and water use is mostly estimated as very few water metres are installed in Dar es Salaam.

Two different versions of the Rapid Assessment are used in this investigation; the one proposed by the World Health Organization in 1982, the other by Economopoulos in 1993. The publication of 1993 is more detailed, which explains some of the differences. But some differences are hard to explain, for instance the oil refining waste loads factors for vegetable oil and olive oil that seem to be swopped. The vegetable oil waste loads factors of 1982 are the same as the waste loads factors of olive oil extraction in 1993. The production of vegetable oil in 1982 had a waste load of 57.5 m^3/ton, in 1993 this is reduced to 6.8 m^3/ton of product or in the case of corn oil even to 1.85 m^3/ton of product. In this investigation the probably more correct values of the 1993 publication are used where possible.

Table 1: Waste loads factors of the two different Rapid Assessment versions compared.

Product:	**Waste water:** WHO 1982	Economop. 1993	**BOD:** WHO 1982	Economop. 1993	**Oil:** WHO 1982	Economop. 1993
Edible oil	57.5	6.8 (m^3/ton)	12.9	24.9 (kg/ton)	6.5	28.1 (kg/ton)
Canned fruits	11.3	(m^3/ton prod.)	12.5	(kg/ton prod.)		
Jam/syrup		2.4 (m^3/ton prod.)	5.1	(kg/ton prod.)	0.6	(kg/ton prod.)
Squash		5.6 (m^3/ton raw mat)		16.8 (kg/ton raw mat.)		
Tomato products		4.7 (m^3/ton raw mat)		1.3 (kg/ton raw mat.)		
Soft drinks	7.1	4.3* (m^3/ton prod.)	2.5	2.1* (kg/ton prod.)		
Cotton fabric	317	265# (m^3/ton prod.)	155	155# (kg/ton prod.)		
Acrylic fabric	210	210# (m^3/ton prod.)	125	125# (kg/ton prod.)		
Domestic	73	30-110 (m^3/person/year)	6.9	16.4-19.7 (kg/person/year)		7.3 (kg/person/year)

* per m^3 of product. # per ton of cotton / acrylic.

The objective of the rapid assessment was to estimate the influent characteristics of the Vingunguti waste stabilization pond system and to identify the major polluters. A map of the sewer was used to select the industries. All industries that might have a sewer-connection to Vingunguti waste stabilization pond system were visited between June 14 and July 29 in 1995.

All industries using water in their process were asked to fill in a questionnaire others were briefly interviewed (for questionnaire see appendix 3). In total 44 operative industries were visited. The major industries were at least visited twice, when possible the production site was visited and related subjects were discussed with the head of production.

The questionnaire existed of questions regarding general information, process information, water supply and usage, amount and characteristics of waste water produced, and treatment and disposal of waste water. In total 20 questionaries were collected (see appendix 3).

2.2 Assessment of waste stabilization pond design (Mara, 1992 and Reed, 1995)

There are many different equations to design waste stabilization ponds, however the influent BOD is always the basis for design. It is not known which design method was used to design the of Vingunguti waste stabilization ponds. But it is known that an estimated BOD-loading based on a fictive population was used for the design.

To indicate the appropriateness of the size of the waste stabilization ponds the design is recalculated using the Waste Stabilization Pond Design Manual for Eastern Africa. This is a handbook for designing, operating and maintaining a waste stabilization pond system in this particular region. The design equations are summarized in the box 3.

1. **Acceptable BOD load**: the temperature is found in literature and used to calculate the acceptable BOD load.

$$\lambda_s = 350(1.107 - 0.002 * T)^{T-25}$$

λ_s = acceptable BOD loading of the pond (kg/ha*day)
T = mean air temperature in the coldest month (°C)

2. **Pond surface area**: the acceptable BOD load together with the influent flow and BOD calculated with the Rapid Assessment are used to calculate the pond surface area.

$$A_f = \frac{10 * L_i * Q}{\lambda_s}$$

A_f = surface area of the pond (m^2)
L_i = influent BOD (g/m^3)
Q = influent flow (m^3/day)

3. **Retention time**: The evaporation rate is found in literature. The design pond depth is used in this calculation to make comparison with the original design possible.

$$\Theta = \frac{2 * A_f * D}{(2 * Q - 0.001 * A_f * e)}$$

Θ = retention time (days)
D = pond depth (m)
e = net evaporation (mm/day)

Note: This equation is based on $\Theta = A_f D / Q_m$, in which the mean flow is $Q_m = (Q - Q_e)/2$, assumed that seepage is negligible the effluent flow is $Q_e = Q - 0.001 A_f e$.

4. **Effluent flow**: The effluent flow of the first pond is calculated and used as influent flow for the second pond.

$$Q_e = Q - 0.001 * A_f * e$$

Q_e = effluent flow (m^3/day)

5. **Faecal coliform removal**: Usually the faecal coliform removal is one of the design parameters. As little information on faecal coliforms is available the removal is calculated afterwards to indicate the appropriateness of the design.

$$N_e = \frac{N}{1 + k * \Theta}$$

N_e = number of faecal coliform per 100 ml effluent
N = number of faecal coliform per 100 ml influent
k = first order rate constant (1/days)

Note: This equation is based on the assumption that faecal coliform removal can be modelled by first order kinetics in a complete mixed reactor. Assuming that $k\Theta << 1$ such that $N_e = N(e^{k\Theta}) \approx N/(1 + k\Theta)$.

Box 3: Waste stabilization pond design equations (Mara, 1992).

The Rapid Assessment provides the influent BOD and flow which are the most important inputs for the design method. Other inputs like temperature, net evaporation, and pond depth are found in literature. The outputs, pond surface area, retention time, and faecal coliform removal, are calculated and compared with the actual design. The design calculations are made for a waste stabilization pond system consisting of four ponds in series. Therefore the effluent flow is an calculated output needed for as input for the calculation of the following pond.

2.3 Waste audit (UNIDO&UNEP)

The Audit and Reduction Manual for Industrial Emissions and Wastes by the UNIDO and UNEP is a guideline for waste audits in industry. This manual describes an extensive method to set up an industrial waste reduction action plan. The method is based on participation with the employees to collect the information needed to make a material balance which indicates the major sources of pollution.

In this investigation relatively simple industrial processes are waste audited in limited time. Therefore the UNIDO-UNEP-method was simplified (see box 4). The result is a simple structured method to identify and where possible quantify waste water prevention options.

Waste audits will be carried out in some major water polluting industries, selected with the results of the Rapid Assessment. These industries will be visited. Data will collected through interviews with the employees.

1 Pre-assessment:
- *Audit focus and preparation*
  This investigation focuses on prevention of waste water. The industrial processes are relative simple and the time span and facilities are limited, therefore a simple waste audit will be carried out. Only major problems will be identified and possible solutions will be recommended.

2 Material balance:
- *Systematical process description*
  Going through the entire process and interviewing several employees must result in a description of the process in terms of unit operations.
- *Determining inputs and quantifying process outputs*
  From the accounting department most figures should be readily available; budgets, payments, sales, water bills etc.. Figures not available should either be measured or estimated; for instance the amount of water used in certain unit operations. Major sources of wastes will be identified by calculating the material balance.

3 Synthesis:
- *Identifying options for waste reduction*
  Options for waste reduction will be identified through interviewing employees and studying literature. The cost for implementation will be estimated.
- *Strategy for cleaner production*
  Recommendations to improve the production process will be made to the industries investigated.

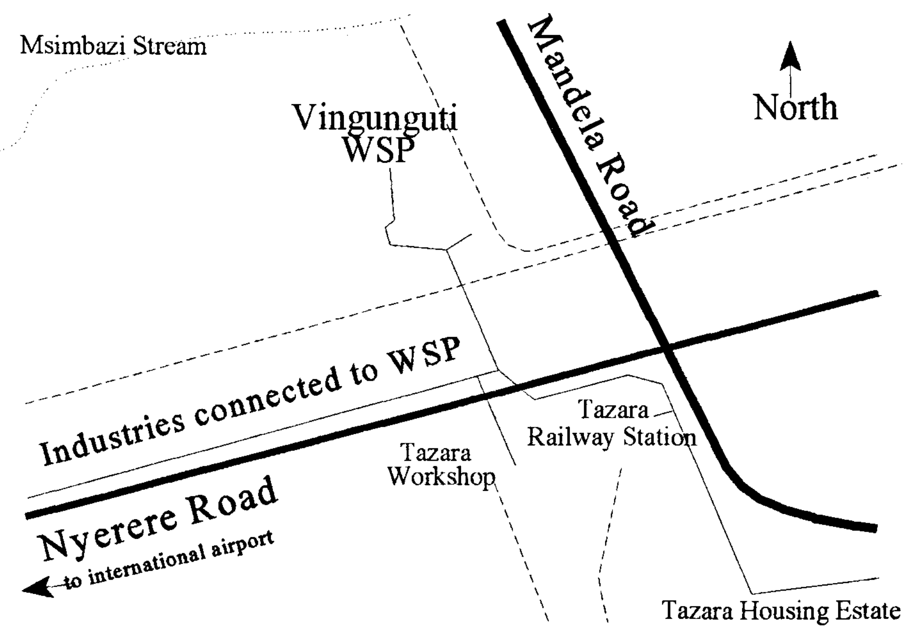
Box 4: Method for simple waste auditing based on UNIDO-UNEP-method.

3 Rapid Assessment of connected industries

A map of the sewer was used to select the industries discharging to the Vingunguti Waste stabilization pond system. The waste water characteristics calculated with the Rapid Assessment will be discussed per industrial sector. In the last paragraph of this chapter, the waste water characteristics of all sectors will be summarized to give an estimate of the Vingunguti waste stabilization pond influent.

3.1 Industries connected to Vingunguti WSP

The sewer leading to Vingunguti waste stabilization pond system is situated north of Nyerere Road (former Pugu Road). The water flows by gravity force to the waste stabilization pond system. Almost all industries situated along the sewerage have been reported to be connected (see Appendix 2). The sewer crosses Nyerere Road only twice, to serve Tazara Railway station, the Housing Estate and Tazara Workshop. For transportation of waste water on this side of Nyerere Road three pumping stations are installed.



Map 1: Sewer flowing to Vingunguti WSP (Thick lines are roads, thin line is the sewer, broken lines are railroads, the dotted line is Msimbazi stream).

The Vingunguti area is known by the National Urban Water Authority as a ' low pressure area' this means that the piped water supply is insufficient. Only on Tuesday and Saturday extra water is injected into the water supply system to assure that all water connections are served. Therefore some companies have their own borehole or a swallow well. Others have additional water supplied by tanker or hand car. All companies have a water storage tank.

Due to load shedding there was no electricity on Tuesday, Thursday and Sunday. Some of the companies had invested in a generator, others were operational during four days a week only. An overview of connected industries is given in table 2.

Table 2: Industries connected to Vingunguti WSP.

ISIC:	Description:	No:
31	Manufacture food, beverage	3
321	Manufacture of textile	2
341	Manufacture paper products	1
3521	Manufacture paints, varnishes and lacquer	2
38	Manufacture fabricated metal products	20
	Selling and repairing cars	11
	Domestic water users	5
	No industrial activity at time of survey*	21
	Total:	**65**

* These are storage facilities, factories under construction, bankrupt factories etc.

3.2 Manufacturing food and beverage

Vegetable oil refining: Coastal Oil

Description:

Crude oil is used to produce edible oil (palm olein) and as by-product raw material for soap is produced. Water storage tanks with a total capacity of 450 m^3 are shared with sister company Zahra Bottlers. In the process of refining water (2.5 m^3/day) and caustic soda (400 kg/day) are used for washing and for deodorization steam is used (total 2.5 m^3/day). Waste water, containing oil and soap, is discharged through a sewer together with the waste water of Zahra Bottlers.

At the moment the factory is operated with 30 employees, 16 hours a day during 5.5 days a week, using 32% of the capacity. A new plant, with a capacity of 100 tonnes per day will replace the old plant in 1996.

Rapid Assessment:

Table 3 shows very big difference between stated and calculated waste water volume (factor 28!). Possibly resulting from the fact that the rapid assessment assumes that seeds are used as raw material while this company uses crude oil. No extraction is done at this factory site. But it is also likely that waste load factors are not very accurate for the Tanzanian situation. For oil refining in Tanzania, including extraction, a waste water volume of 60 m^3/t was calculated with the Rapid Assessment, while the analysed volume was 0.3 m^3/t (Scheren, 1994).

Squashes, jams, snacks and tomato products: Tropical Foods Ltd

Description:

This company produced 221 tonnes of food products in 1994, 10% of the production capacity only. The target for 1995 is to produce twice as much. 500 people are employed. The waste water, 4.9 m^3/day, is discharge to the sewer without treatment.

Rapid Assessment:

For the calculations the assumption is made that one third of the production was tomato products, one third squashes and one third jams.

Table 3: Food and beverage manufacturing (Economopoulos, 1993).

Company:	*Questionnaire data:* *Production:* *t/year 1994*	*Waste water:* *m^3/year*	Calculated data: **Waste water:** m^3/year	**BOD*:** t/year	**TSS*:** t/year	**Oil*:** t/year
Coastal Oil	*4,150*	*1,000*	28,220	103	102	116
Tropical Foods	*221*	*1,400*	936	1.4	0.5	
- tomato prod.			346	0.1	0.2	
- squash			413	1	0.2	
- jam/syrup			177	0.3	0.1	
Zahra Bottlers	*1,026*	*10,000*	4,412	2	0.7	
	Total:	***12,400***	**33,568**	**106.4**	**103.2**	**116**

*Terminology explained in appendix 4.

Soft drink factory: Zahra Bottlers

Description:

This factory produces soft drinks under licence. The concentrate used to make syrup is imported from the United Kingdom. This syrup is mixed with treated water, sugar and carbon dioxide and bottled. Water for soft drink production is treated by adding hypochlorite and thereafter filtering through a sand filter and a carbon filter. Most waste water is produced in the bottle-washer which uses sodium hydroxide and 50 m^3 of water per day. The rest of the waste water is produced when backwashing the filters (3 m^3/day) or cleaning the equipment (1 m^3/day). All waste water is discharged through the sewer without treatment.

The factory was operated at 50% capacity in 1994, with 60 employees, during 12 hours a day, 5.5 days a week. Target for 1995 is to occupy 73% of the capacity.

Rapid Assessment:

The stated waste water volume is more than twice as much as the volume calculated with the Rapid Assessment. Peter Scheren reported a similar difference; the analysed waste water volume of Nyanza Bottling in Tanzania was three times as much as the volume calculated with the Rapid Assessment method (21 m^3/t instead of 7 m^3/t). However, he reported that the BOD of the analysis was lower than the BOD calculated with the Rapid Assessment (70 g/m^3 instead of 400 g/m^3) (Scheren 1994).

3.3 Manufacture of textiles

Cotton: Calico Textile

Description:

This company produces cotton fabric and some polyester. Spun cotton from the local mills is the raw material. Activities of Calico are: dyeing in batches and weaving. The production capacity is 4.2 million metres per year but only 10 % of the production capacity is used. The target for 1995 is 3 million metres and the expectations is 0.42 million metres. There are 80 people employed and the factory produces 2 to 3 days a week as result of power rationing and water shortage. Calico Textile uses about 100,000 litres a day, normally about 1 million litres a months. A borehole was not possible at this site. The waste water is directly discharged to the sewer.

Rapid Assessment:

The water shortage is probably one of the reasons that the rapid assessment overestimated waste water volume.

Synthetics: Pattex Knitwear manufacturing (T) Ltd

Description:

Acrylic fibres are dyed and manufactured into outerwear knitted garments. Seventy employees are working in one shift. Waste water is directly discharged to the sewer.

Table 4:Textile (Economopoulos, 1993).

	Questionnaire data:		Calculated data:		
Company:	***Production:*** *t/year 1994*	***Waste water:*** *m^3/year*	**Waste water:** m^3/year	**BOD:** t/year	**TSS:** t/year
Calico	*84*	*12,000*	22,260	13	6
Pattex	*2.7*	*3,600*	567	0.3	0.2
	Total:	*15,600*	22,827	13.3	6.2

Rapid Assessment:

Surprisingly the calculated waste water volume is less than one sixth of the stated volume.

3.4 Manufacturing paper products: Paper Products (T) Ltd

Description:

This company produces inner and outer cartons. Raw materials are paper, white lined chipboard, kraft liner, fluting, inks etc.. This company employs 130 people. In 1994 water usage was 5920 m^3, needed to produce 1458 ton product, 22% of the capacity. Water is used for cooling (10 m^3/day), cleaning (9.7 m^3/day) and washing (3 m^3/day). Waste water is discharged through the sewer untreated.

Rapid Assessment:

From the World Health Organization manual for Rapid Assessment no data are available to estimate the waste water characteristics of this type of industry. As the waste stabilization pond investigated is a small watershed this industry can not be neglected. To account for this industry the waste water characteristics are assumed to be similar to domestic waste water.

Table 5: Paper products (Economopoulos, 1993).

Company:	*Questionnaire data:* *Waste water:* m^3/year	Calculated data: **Population** equivalent:	**BOD:** t/year	**TSS:** t/year	N_{total}: t/year	P_{total}: t/year	**Oil:** t/year
Paper Prod.	*5920*	108	1.9	4.2	0.3	0.1	0.8

3.5 Manufacture other chemical products

Paints, varnishes and lacquers: Galaxy Paints and Sadolin Paints:

Description:

Galaxy Paints produced about 472,705 litres of paints in 1994, using 4 m^3 of water per day for processing and 1 m^3 for cleaning. Waste water produced when cleaning contains pigments. Settling and sedimentation are used as treatment before the water is discharged to the sewer.

Sadolin Paints produced 680,000 litres (57% of production capacity) in 1994 using1,700 m^3 water. Water is used for cooling (2 m^3/day) and for washing (1 to 2 m^3/day). The company employs 40 people, working in two shifts. Before the water is discharged to the sewer it flows through a settling pit. The company considers to recycle the water used for cooling.

Rapid Assessment:

The World Health Organization classifies the waste water pollution of this type of industry as negligible. However this is not true when investing the influent of a waste stabilization pond. As no other data are available the waste water will be assumed to be of domestic use.

Table 6: Paints (Economopoulos, 1993).

	Questionnaire data:	Calculated data:					
Company:	***Waste water:*** *m^3/year*	**Population** equivalent:	**BOD:** t/year	**TSS:** t/year	**N_{total}:** t/year	**P_{total}:** t/year	**Oil:** t/year
Galaxy	1,250	23	0.4	0.9	0.07	0.02	0.1
Sadolin	1,700	31	0.6	1.2	0.1	0.03	0.2

3.6 Metal industries

Electroplating

Description:

On the site of the Small Industrial Development Organisation (SIDO) 19 small scale industries are operating. There are 14 small scale metal workshops of which 3 use water for electroplating. Tanzania Galvanizing, a fourth electroplating company, is temporary out of production. In table 6 the waste water characteristics of the electroplating are shown.

Table 7: Electroplating (WHO, 1982).

Company:	*Questionnaire data:* *Anodes:* *type*	*Waste water:* *t/year*	*m^3/year*	**Calculated data:** **Waste water:** **m^3/year**	**Chemicals:** **kg/year**	
Cyclebells	*Zn*	*0.27*	*390*	490	Zn	60
					CN	9
Meida MS	*Cr_2O_3*	*0.002**	*65*	65*	Cr^{6+}	0.5
					Cr_{totaal}	1
Tazara WS	*Cr_2O_3*	*0.135*		4900	Cr^{6+}	40
					Cr_{totaal}	100
	Cu	*0.04*		60	Cu	0.4
					CN	0.8
	Ni	*0.01*		15	Ni	0.04
	Zn	*0.224*		406	Zn	50.2
					CN	728
YMCA	*Zn*	*0.03**	*52*	52*	Zn	6.4
					CN	0.9

*Waste volume of questionnaire used to calculate anode-consumption!

At the SIDO site there is also a small scale grey iron foundry. The water usage of this foundry is about 47 m^3 per year. Most of the water evaporates in the oven.

Table 8: Small scale foundry (assumption: 25% of water supply ends up as waste water) (WHO, 1982).

	Calculated data: Estimated production:	Waste water:	SS:	Oil:
Foundry	7 t/year	12 m^3/year	0.0003 t/year	0.002 t/year

Rapid Assessment:

The calculated data show that the waste water volume produced by these industries is small. But chemicals used are harmful to the environment. The concentration estimated with the Rapid Assessment of the various chemicals in the waste water exceed the Tanzanian Standards (appendix 7).

Manufacture of fabricated metal products

Description:

In this very diverse sector eight companies used water in their process. Three remarkable companies will be discussed in this paragraph.

Tanzania Autoparts produces oil and air filters for cars. The only information this company contributed to the rapid assessment was that they produce 4800 m^3 of waste water per year. According to literature hydro chloric acid is used to pickle steel. Resulting 7 m^3 of waste water are discharged per year, having a pH value of - 0.3 and a chloride contents of 118,800 mg/l (Ministry of Land, Housing and Urban Development, 1980). However the company denied this, thus the literature data are not used in this Rapid Assessment.

Tazara Workshop employs 500 people to make spare parts for trains. This is the largest company in this branch. The piped water supplied is not sufficient. There are two boreholes one near the workshop another near the station. The workshop uses about 10,000 litres of water per day. Water is used in the process for steam generation, for cooling, washing, electroplating (see table 7) and for domestic purposes.

This company uses large amounts of oil. Some waste oil is collected and burnt in the furnace. The oil waste sludge resulting from washing locomotives is discharged to the sewer. Which gives problems with the pumping station. The pumping station is presently not working. As a result the waste water is discharged through the storm water sewer directly to the Indian Ocean. Which is a shame since a simple solution can be found in cooperation with the responsible institutions. An oil-water-separator can be easily produced by this company to treat the waste water before discharging it to the Vingunguti waste stabilization ponds.

Another interesting company is *Yuasa Battery* which produces dry automotive lead-lead oxide batteries, 6823 pieces in 1994. This company employs 73 people. In 1994 water was supplied by tankers since the piped supply was not sufficient. Water usage is 45,000 litres per year. Most water is used for cooling the battery plates. The waste water is directly discharged to the sewer. No information is available on the lead concentration in the waste water.

Rapid Assessment:

The metal industry is a diverse sector in this investigation but no data are available to make estimates of waste water characteristics. Using the Rapid Assessment the only data available that probably resemble the waste water characteristic of this sector are the waste load factors of household appliances or motor vehicles manufactures. The total waste water volume of the companies in this sector is divided by the waste water volume per ton of iron sheet per year, as used in the Rapid Assessment. With this fictitious production figure the waste water characteristic of this sector is estimated, results are shown in table 9.

Table 9: Metal product manufacturing (WHO, 1982).
(assuming that the waste water characteristic can be resemble that of companies producing house hold appliances)

Questionnaire:	**Calculated data:**					
Waste water:	**Estimated production:**	**BOD:**	**COD:**	**TSS:**	**TDS:**	**Oil:**
m^3/year	equiv. to t of iron sheet/year	t/year	t/year	t/year	t/year	t/year
15,149	275	5.3	22.6	2.3	6.2	0.9

3.7 Selling and repairing cars

Description:

There are 11 companies operating in this branch. The major pollutant in the waste water of the companies in this branch in waste oil. Estimated waste oil volume is 119 m^3/year. It is not clear what amount is discharged to the waste stabilization ponds as not all oil is poured into the sewer and some companies have the workshop connected to the storm water sewer.

Rapid Assessment:

The Rapid Assessment has no waste load factors for companies in this branch. Assuming that the water is used for domestic purposes an estimate of the waste water characteristics can be made.

Table 10: Car maintenance (Economopoulos, 1993).

Questionnaire data: *Waste water:* m^3*/year*	Calculated data: **Population** equivalent:	**BOD:** t/year	**TSS:** t/year	N_{total}**:** t/year	P_{total}**:** t/year	**Oil:** t/year
17,324	315	5.7	12	1	0.3	2

3.8 Domestic water use

Description:

Tazara Railway Station and the Tazara Residential Flats are connected to the sewer. The station employs 700 people while the flats houses 290 families. Sewered population consists of about 1160 people living in the flats. More households may be connected, but these are not registered. Then there are some companies not yet accounted for because a unspecified amount of water is used, not in a production process but purely domestic.

Rapid Assessment:

The rapid assessment probably over estimated the water domestic water usage because there is a constant shortage of water. Due to the break downs in the pumping system not all waste water reaches the Vingunguti waste stabilization ponds, with consequent flooding of residential area's.

The companies with only domestic water use employ 795 people (Achelis, Bandag, General Tyre, Showmax and Tazara Railway station).The Rapid Assessment has no waste loads for domestic water usage in companies therefore the waste load for retail trading companies was used.

Table 11: Domestic waste water (Economopoulos, 1993).

		Waste water: m^3/year	**BOD:** t/year	**TSS:** t/year	N_{total}**:** t/year	P_{total}**:** t/year	**Oil:** t/year
Inhabitants	1,160	63,800	21	45	3.8	1.1	8.5
Employees	795	17,410	5.8				

3.9 Total waste water flow to the Vingunguti waste stabilization ponds

The amount of waste flowing to the Vingunguti waste stabilization ponds is estimated to be $1.6*10^5$ m^3/year with an estimated BOD of 160 t/year. The water use is suppressed due to water shortage. If water supply improves the water use might rise to $1.9*10^5$ to m^3/year.

An unexpected large contribution is made by the domestic users, responsible for more than 50% of the waste water flow. However the domestic water use is believed to be much lower as very little water is supplied to the residential area. Other large waste water volumes are produced in the Food and Beverage sector (8%), the Car Maintenance sector (11%), the Textile sector (10%) and the Metal Product Manufacturers (10%).

The BOD originates for 66% from the oil industry, 17% from domestic use, and 8% from the Textile sector. The BOD of the oil industry is expected to be lower as the raw material is crude oil and not seeds as assumed by the Rapid Assessment. The domestic BOD is also expected to be lower as the Rapid Assessment is based on 18.1 kg BOD per capita per year while a value of 14.6 kg/capita/year is recommended for East Africa in other literature (Mara, 1992). As no other data are available further calculation in the next chapter will be done relying on the Rapid Assessment data. Different cases will be calculated to consider the inaccurateness of the Rapid Assessment Data.

Table 12: Total waste water flow to Vingunguti waste stabilization ponds.

Sector:	*Questionnaire:* *Waste water:* m^3/year	Calculated: **Waste water:** m^3/year	**BOD:** t/year	**COD:** t/year	**Oil:** t/year	**TSS:** t/year
Food and beverage	*12,400*	33,568	106.4		116	103.2
Textile	*15,600*	22,827	13.3			6.2
Paper products	*5,920*		1.9		0.8	4.2
Paint manufacturing	*2,950*		1.0		0.3	1.7
Metal products	*15,149*		5.3	22.6	0.9	2.3
Electroplating		5,988				
Foundry	*12*					
Car maintenance		17,324	5.7		0.2	2
Domestic		81,210	26.8		8.5	45
Total:	***156,553****	**184,948***	**160.4**			
Heavy Metals:		**kg/year**				
Zinc	Zn	117				
Chrome	Cr^{6+}	40				
	Cr_{total}	100				
Copper	Cu	0.4				
Nickel	Ni	0.04				

*for missing values the estimates of the rapid assessment (questionnaire) are used.

4 Assessment of Vingunguti waste stabilization pond design

Design according to unadapted standard formula's is mentioned as a reason for the poor performance of waste stabilization ponds in Tanzania. Different equations to design waste stabilization ponds can be used, however the biological oxygen demand (BOD) of the influent is always the basis for design. It is not clear which method was used to design the Vingunguti waste stabilization ponds. But it is known that an estimated BOD-loading based on a fictive population was used for designing the ponds. To indicate the appropriateness of the design calculations will be made using a design method adapted to the East African situation. As input the BOD estimates of the Rapid Assessment are used.

4.1 Vingunguti waste stabilization pond system

The Vingunguti waste stabilization pond system was constructed in 1974. Between 1984 and 1988 the ponds have been rehabilitated and a dumping station for vacuum tankers has been built. The system treats domestic and industrial waste water. At the site there is a swamp which is used as storm water basin and sludge disposal site.

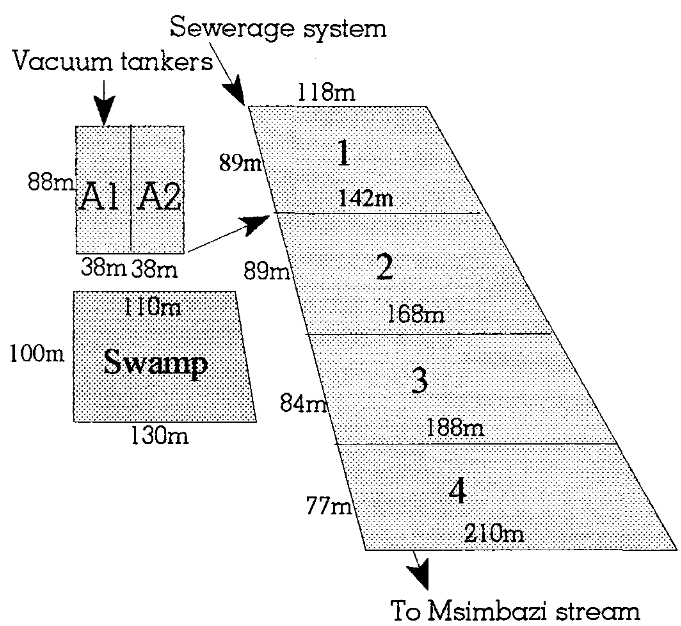


Figure 1: Vingunguti WSP-system.
(Pond A1 and A2 are anaerobic, 1 and 2 facultative and 3 and 4 maturation ponds)

The ponds' site have been encroached by unplanned residential houses. There are now flow devices, there is no control and no fence. Illegal dumping of oil effluents has been observed. As well as fishing in the last pond. The effluent of the waste stabilization pond system is discharged to Msimbazi stream which is used for irrigation in urban agriculture, fish farming, sand winning and washing. Msimbazi stream transports the water to the Indian Ocean. In 1980 the water quality of Msimbazi stream was assessed as little better than an open sewer (Ministry of Land, 1980).

The anaerobic ponds are not redimensioned in this chapter as the only information available was the verbal statement that the dumpings of the vacuum trucks at Vingunguti had temporarily stopped. Because the anaerobic ponds need to be emptied as accumulated waste rises above the water surface under the inlet.

Therefore the present influent of the anaerobic ponds is unknown. The flow from the anaerobic ponds (A1 and A2) to the second facultative pond (2) was designed to be 240 m^3/day. In 1990 this flow was measured to be 118 m^3 /day (Mgeyekwa, 1990). In redimensioning the facultative ponds the design flow will be used as no recent information is available.

The four other ponds will be designed as facultative pond (for design model see appendix 5). This is not entirely correct since the last two are considered to be maturation ponds. Maturation ponds are usually designed on pathogens removal. But no information about influent pathogens is available. According to literature the normal retention time for BOD removal is sufficient for pathogen removal if the total retention time exceeds 20 days (Reed, 1995). Therefor the ponds will be designed as facultative pond, as a control the faecal coliform removal is calculated afterwards.

4.2 Redimensioning Vingunguti waste stabilization pond system

Important inputs for the design are the waste water flow and the BOD load as estimated with the Rapid Assessment method (chapter 3). As the interpretation of the Rapid Assessment results is not unambiguous this pond design is calculated for different cases;

Rapid Assessment Case:

Relying on the results of the Rapid Assessment only, the waste stabilization ponds would be designed for a waste water flow of 507 m^3/day and for a BOD of 872 g/m^3. The first pond area would be 13,821 m^2. Compared to the actual design the flow is a factor 3.47 less while the BOD is a factor 4.56 higher. This results in a surface area which is 4221 m^2 larger than the actual design. And the total retention time would be 68 days instead of the 28 days of the actual design.

Large differences were observed between Rapid Assessment results and waste water data acquired from the questionnaires. The questionnaire date might be more reliable as companies are aware of their water use. Due to water shortage in the area all companies need a water storage tank, sometimes they need to collect water by tanker. Design can be calculated relying on the questionnaire data for the waste water flow (429 m^3/day) and the BOD estimation of the Rapid

Assessment (1,030 g/m^3). This results in a first pond area of again 13,821 m^2 and a total retention time of 79 days. The pond area is unchanged as the BOD has remained 441 ton per day. The retention time is longer as less water flows through the ponds.

Combining the flow and BOD of this case with actual design would lead to a surface loading (= organic loading) of 460 kg/ha/day for both variants of this case. According to design method the permissible BOD depends on the mean air temperature in the coldest month (Mara, 1992). In the design calculation 23.45 °C was used resulting in a permissible BOD load of 230 kg/ha/day (Ministry of Tourism, 1994). A BOD load of 460 kg/ha/day would mean that the Vingunguti ponds are overloaded. But other literature states that this loading is within the acceptable range of 200 to 500 kg BOD /ha/day (Environmental, 1990).

Adjusted BOD Case:

In the Rapid Assessment Case the probably more reliable waste water volumes of the questionnaire were used while the BOD of the Rapid Assessment was accepted as reliable. The underlying hypothesis is that the water shortage results in more concentrated waste water. However the large differences between Rapid Assessment and questionnaire data can also be explained by the fact that the actual production process differs from the process on which the Rapid Assessment is based.

Rejecting the hypothesis that the waste water is more concentrated and assuming that the waste water volume of the questionnaire is correct we can calculate the BOD contents of the waste water. Using the Rapid Assessment method normally the BOD is based on the production. But now the BOD is adjusted to the questionnaire waste water flow calculated with the same waste load factors given by the Rapid Assessment.

In this case a flow of 429 m^3/day and a BOD of 390 g/m^3 are the inputs for the design calculations. As the BOD contents decreased, the calculations result in a smaller first pond area of 5,227 m^2 and a shorter total retention time of 30 days.

It is also possible to adjust the BOD contents of the waste water of domestic users. The Rapid Assessment indicates a BOD of 18.1 kg/capita/year while other literature recommends 14.6 kg/capita/year for East Africa (Mara, 1992). This means that the BOD contents of the influent decreases to a value of 363 g/m^3. The first pond area would decrease to 4,870 m^2 and the total retention time would decrease to 29 days.

Combining flow and BOD of this case with the actual dimensions of the Vingunguti ponds results in a BOD loading of 174 respectively 162 kg/ha/day. This would mean that the ponds are under loaded.

Increased Production Case:

Most of the companies are producing on low capacity due to circumstances like electricity load-switching and insufficient water supply. For instance Coastal Oil, now operating at 32% of its maximum production capacity, is planning to open a new production line which will double the capacity. Tropical Food and Calico Textile are both operating at 10%, and Zara Bottlers at 50% of their respective production capacity. If these industries would be operating at 100% of production capacity, the expected waste water flow would be 879 m^3/day and the BOD concentration 2,572 g/m^3. Such an increase in production capacity utilisation is not likely. More realistic is that the production would increase to the 1995 targets set by the industries. This would result in a flow of 661 m^3/day and a BOD of 1,362 g/m^3. Then the first pond surface area would be 28,139 m^2 and the total retention time 102 days.

Combining the flow and BOD of this case with the actual design gives a BOD loading of 2355 kg/ha/day for the 100% production capacity utilization and 938 kg/ha/day for the case that the industries produce according to their 1995 targets. Both BOD loadings indicate that the Vingunguti ponds would be severely overloaded.

Table 13: Waste stabilization pond design using different cases (see appendix 5).

		Cases:			**Actual Design:**
		Adjusted BOD*	***Rapid Assessment^***	***Increased Production"***	
Influent flow	(m^3/day)	*429*	*429*	*661*	1,762
Influent BOD	(g/m^3)	*364*	*1,030*	*1,362*	284
Pond 1:					
-surface area	(m^2)	*4,870*	*13,821*	*28,139*	9,600
-retention time	(days)	*15*	*41*	*53*	7
Pond 2:					
-surface area	(m^2)	*2,527*	*7,463*	*15,491*	11,600
-retention time	(days)	*7*	*18*	*24*	7
Pond 3:					
-surface area	(m^2)	*2,594*	*7,660*	*14,058*	13,776
-retention time	(days)	*4*	*12*	*15*	8
Pond 4:					
-surface area	(m^2)	*1,889*	*5,657*	*10,453*	14,175
- retention time	(days)	*3*	*8*	*10*	7
Effluent flow	(m^3/day)	693	738	1,037	2,002
Effluent BOD	(g/m^3)	*8*	*24*	*31*	< 5

* Both industrial and domestic BOD adjusted.
^ Flow of questionnaire, BOD of Rapid Assessment
" If industries produce according to 1995 targets.

4.3 Actual Design

If the actual flow and BOD are used to recalculated the design the dimensions of the pond would differ from the present dimensions. The recalculated first pond surface area is larger while in total the surface area is smaller. The recalculated total retention time is shorter. It is very well possible that the location and the removal of pathogens have influenced the actual design. If recalculation are done with the actual pond surface area's a waste stabilization pond system with a better faecal coliform removal is the result. The total retention time is now the same as in the actual design. But the effluent BOD is 7 mg/m^3 which is higher than the actual design value. Overall the used design method does not differ very much from the method used in this investigation. It is mainly the BOD loading used for design that makes the difference.

4.4 Vingunguti waste stabilization pond performance

The calculations show that an effluent BOD < 5 g/m^3 can not be achieved with the waste stabilization pond under present condition. However 30 g/m^3 BOD is permitted by the Tanzanian Effluent Standard for direct discharge. The waste stabilization pond effluent would exceed this Standard only if the industries increase their production above their 1995 targets.

Two out of three cases indicate that the Vingunguti ponds are overloaded. As future prospective it is realistic to expect an increase in waste water flow and BOD as many companies want to increase production. Improved facilities like power and water supply can make this possible. Some companies facing operational problems might have to close. But several new companies are likely to be connected in future. As there companies under construction and other companies presently not connected to the sewer have asked for a connection.

At present the performance of the Vingunguti waste stabilization pond is below expectations. A more detailed investigation should result in implementation of an action plan to assure good performance in future. As little room for expansion is available at the Vingunguti waste stabilization pond site, such an action plan should include simple measures to improve the performance of the system as well as waste water prevention measures. Simple measures to upgrade the Vingunguti pond are given in box 5. Waste water prevention options will be discussed in the next chapter.

- Operation and Maintenance:
  Guidelines must give a clear picture of the different tasks, when they have to be done, and whom is responsible. Tasks that must be included are: taking samples, preforming measurements, registration of dumpings, removal of accumulated solids, removing scum from the facultative and maturation ponds, scum spraying on anaerobic ponds, cutting the grass, and repairing any damage to the embarkment or external fences. Furthermore a sign must be placed to make the neighbourhood inhabitants aware fact that using the water from the pond is dangerous for their health.

- Rehabilitation of the ponds:
  Measurements should indicate the details of the pond performance and wether it is necessary to implement the following options:

  * desludging pond if necessary;
  * avoiding short circuiting by installing baffles and/or multiple inlets, preferable long diffusers;
  * to reduce the algae in the effluent multiple depth withdrawal should be practised, all withdrawals should be done at least 0.3 m below the water surface;
  * to reduce algae and suspended solids in the effluent an intermittent sand filter, micro strainers, grass plots, or a rockfilter can be installed.

Box 5: Simple measures to improve performance of Vingunguti WSP (Mara 1992, Reed, 1995).

5 Waste audits in selected industries

Waste audits are carried out to see whether there are waste water prevention options to minimize the waste load entering the Vingunguti waste stabilization ponds. The results of the Rapid Assessment are used to select three major water polluters for a waste audit;

1) Zahra Bottlers Ltd, a soft-drink bottler was selected because this is the second largest water user. The largest water user is Calico Textile, a textile factory which had all kinds of operational problems, therefore could not cooperate with the investigation.
2) Tanzania Cyclebells Manufacturers Ltd, a small scale electroplating company, was also selected. This company uses chemicals that could affect the performance of the waste stabilization pond performance. As several other small electroplating industries are operating in the area this waste audit could set an example.
3) During the data collection for the Rapid Assessment it was observed that disposal of waste oil was a common problem in the car maintenance sector as well as in the metal sector. Therefore an inventory of waste oil disposal options is made.

5.1 Zahra Bottlers Ltd

Zahra Bottlers is a soft drink bottling plant, with 60 employees. There is one production line where Vimto, Schweppes, Crush, and Sports Cola are bottled in batches. The soft drink is bottled in 250 ml bottles of which 24 fit in one crate. About 1200 crates are filled each day. The mass balance shows that water is an important production input.

Waste water prevention options:

1) Water recycling in the bottle washer

Description:

In this machine the bottles are turned upside-down and cleaned by water-jets in three different section. The first section uses a 10% caustic soda solution, the second section uses hot water and in the third section cold water is used. The caustic soda solution is recycled. Every hour the caustic soda concentration is checked, and if necessary caustic soda is added. The water used in the last two sections is directly discharged.

Option:

At present the bottle washer uses about 42 litres of water per crate of 24 bottles. In bottle washing it is common to reuse the relatively clean water of the last rinsing in the first section of the bottle washers where the bottles are dirtiest. However in the bottle washer used by Zahra Bottlers the water in the first section is recycled. Water from the cold section could be reused in the hot water section. In this way about 40% (20 m^3/day) of the water used in this machine can be saved.

Input:	Unit operation:	Output:
Water (8.7 m^3/d) *Calcium hypochlorite (1.5 kg/d)*	Water treatment	*Clean water (7.5 m^3/d)* *Waste water (1.2 m^3/d)*
Concentrate *Clean water (1 m^3/d)* *Water (1 m^3/d)*	Syrup preparation	*Syrup (± 1 m3/d)* *Waste water (1 m^3/d)*
Bottles(28800/d) *Water (50 m^3/d)* *Caustic soda (80 l/d of 15%)*	Bottle washer	*Clean bottles* *Waste water (50 m^3/d)*
Syrup (± 1 m3/d) *CO_2* *Clean water (± 6.5 m^3/d)*	Soft drink mixing	*Soft drink (± 7.5 m^3/d)*
Soft drink (± 7.5 m^3/d) *Bottles (28800/d)*	Bottle filler	*Bottled soft drink (7.2 m^3/d)* *Wasted (± 0.3 m^3/d)*

Estimated total water usage: 69.7 m^3/d.
Soft drink produced: 7.2 m^3/d, 28800 bottles.
For each bottle of 250 ml softdrink produced 2.4 liter of water is used.

Box 6: Mass balance of the soft drink bottling process.

Presently there is one point at which the waste water leaves the bottle washer. Some changes should be made to collect the cold water and lead it to the boiler for heating. Possibly a buffer tank is needed. Investment cost are estimated to be 120,000 TSh (≈200 US$). Cost saved by saving 20 m^3/day is 2,900 TSh/day (≈ 4.8 US$/day). Hence the payback period is 42 days.

2) Reduce water use of water treatment

Description:

Water supplied by National Urban Water Authority is stored in three tanks of 150 m^3 each. The water used for soft drink preparation is treated with calcium hypochlorite (0.2 g/l). Thereafter the water is led through a sand filter and a carbon filter. The sand filter is backwashed every day using 1 m^3 of water, the carbon filter every week also 1 m^3 of water. For each cubic metre of water cleaned, 0.16 m^3 waste water is produced.

Option:

Less waste water would be produced if less water could be used for backwashing the filters or when the waste water produced could be reused.

Since Zahra Bottlers has its own laboratory it is possible to test whether water can be used when backwashing the filters, whether it is necessary to backwash the sand filter each day, and to test whether the water is safe for domestic use (for example cleaning to floor of the bottling hall). If the water is reused an extra storage tank is needed.

3) Improve efficiency of the bottle filler

Description:

The bottle filler is not working optimal. This results in loss of product. From visual observation it was estimated that one in ten bottles is only half filled. Approximately 360 litres of soft drink is wasted each day (5% of production). Causing a daily superfluous production of approximately 3.6 m^3 of waste water.

Option:

Maintenance and repair could improve the efficiency of the filler machine. Zahra Bottlers has the know-how to investigate the filler machine. Possibly spares are needed, these costs can not easily be estimated. But the cost of spilled production and water is estimated to be 48,000 TSh/day (≈ 80 US$/day).

4) Learning from Canady Dry & Schweppes

Description:

Zahra Bottlers produces under license and once every 3 to 4 months an Canady Dry - Schweppes- expert visits the factory. This expert advises on proper soft drink preparations. Sometimes samples are airmailed to Great Britain for quality control. Zahra Bottlers had advice on administrative and sales matters and received uniforms.

Option:

Contacts with Canady Dry and Schweppes could be used to get information about production efficiency and environmental issues. Short courses for the management would be interesting to catalyse process innovations.

5) Participate on present and future governmental policies

Description:

Control and enforcement of environmental laws is hardly practised in Tanzania. Still it is good management practise to be aware of present and future governmental policies. Several governmental institutions pay regular visits to the company. The quality of the product is also controlled by Section Nutrition of the Ministry of Health and the Tanzania Bureau of Standards (four times a year). Labour Department controls safety aspects.

Option:

Zahra Bottlers should use the visits for collecting information.

6) Controlling water bills

Description:

Every month the National Urban Water Authority (NUWA) registers the reading of the water metre. According to the Bottlers administration a fixed rate of 33,350 TSh (≈56 US$) per months is payed to the Water Authority. If the piped supply is insufficient water is supplied by tanker which costs 11,500 TSh for 9 m^3 (≈ 2 US$/$m^3$). Zahra Bottlers asked the Water Authority to supply properly but plans no further action if the water supply remains irregular. According to the Water Authority bills are made according the water metre, 145 TSh/m^3 (≈ 0.2 US$/m^3), 102874 TSh (≈171 US$) was paid in September 1995.

Option:

Zahra Bottlers should keep a record of the readings of their water metre and control the bills payed to the Water Authority. This will strengthen the arguments for water saving.

Table 14: Cost of water supply.

	TSh/month	TSh/m^3
NUWA bill to Zahra	102,874	67*
Industrial metre	222,343*	145
Minimum rate no metre	333,500	2.2*
Water by tanker	1,959,174*	1278

* Calculated using 1533 m^3/month.

7) Being aware of sewerage regulations

Description:

Zahra Bottlers is not aware of the Tanzanian effluent Standards. The company stated that no payments are made to the Dar es Salaam Sewerage Department. Maybe the company pays for the sewerage services together with the water bill. Another possibility is that the sister company makes payments for Zahra Bottlers since the connection is registered under Bobby Soap.

Options:

The company should take notice of the effluent standards (see appendix 7). A laboratory is available to check whether the effluent is conform the standards. Zahra Bottlers should check wether payments are made for the sewerage services. If the waste water is discharged illegally.

5.2 Tanzania Cyclebells Manufacturers Limited

On the site of the Small Industries Development Organisation (SIDO) 4 small scale electroplating companies are situated. These companies face similar problems. Tanzania Cyclebells Manufacturers was chosen as an example. This company used to produce cycle bells until the Tanzanian market opened for import of bicycles. The cycle bells produced in Tanzania were too expensive. Presently the Cyclebells Manufacturers works on orders. Nowadays about 10 people are employed. The activities are welding, drilling, cutting, bending and electroplating. Since most water and chemicals are used in electroplating this waste audit will focus on the electroplating process as described in box 7.

Problems identified by the company itself are: - irregular jobs sometimes no work at all - and there are difficulties in buying cyanide because it is not produced locally and can only be imported with permission of the government.

Input:	Unit operation:	*Output:*
HCl 0.3% (500 l/d)	Cleaning	*Waste water (500 l/d)*
	Mechanical derusting	
Water (100 l/d)	Rinsing	*Waste water (100 l/d)*
*ZnO (4.25 kg/d)** *ZnCN (5.6 kg/d)** *NaOH (1.1 kg/d)** *Water (28 l/d)** *Zinc Anode (1 kg/d)*	Electroplating	*Waste water (28 l/d)**
Water (800 l/d)	Rinsing	*Waste water (800 l/d)*
*Passivation salt (0.02 kg/d)*** *Nitric acid (0.05 kg/d)* *Water (4 l/d)*	Blue passivation	*Waste water (4 l/d)*
Water (100 l/d)	Rinsing	*Waste water (100 l/d)*

* These amount these amount are estimated using 1000 litres of fresh electroplating liquid every half year and add 100 litres of fresh electroplating liquid every week.
** Passivational salt is traded by the name Technobright and contains zinc metal, chloride and boric acid.
Note: Costumers are charged by the difference in weight before and after electroplating (1000 TSH/kg) or if sheets are electroplated by surface area (1000 TSh/m2).

Total amount of waste water: 1532 l/d.
Anodes use: 3 anodes of 22.5 kg per 3 months, per year 270 kg anode.

Box 7: Mass balance of the electroplating process.

Options for waste water prevention:

1) Reuse of acid solution

Description:

A solution of hydro chloric or sulphuric acid is used to clean the objects before electroplating. The company was advised to place a roof over the hydro chloric acid bath which is placed outside in the sun. The company decided not to place the roof because heat of the sun makes the cleaning process less time consuming and the roof would be destructed by the acid vapours anyway. The workers who work with the acid have been given boots to protect their feet which they do not use, and they are advised to drink milk each day. The milk is thought to compensate for the inhaling of the acid vapours.

Options:

The acid bath should be covered by a lid to reduce vapours. This will result in better cleaning of the objects and a better working environment. The lid can be made by the company itself on low costs. Safety and health issues like this should be discussed with management and employees to find an acceptable solution.

This should result in a responsible attitude of the workers and the management. Adequate equipment should be applied by the company and should be used by workers (what is wrong with the boots ?).

Presently the acid solution is poured away after a job is done, while the acid solution might still be strong enough to clean another job. The acidity of the bath can be measured easily with an indicator, or a pH-metre. If the acidity of the bath is not strong enough then the solution can be upgraded for reuse by adding a concentrated acid solution. This will save money on the long term and environment on short term. The acid solution should never be discharged to the soil. If the solution must be discharged to the sewer it must be neutralised first (conform the standards: pH 6.5 to 8.5). Neutralizing can be done with caustic soda. Reusing the acid might make the acid bath last twice as long, this would save approximately 0.25 m^3 water per day (9 TSh/day).

2) Reduce chemical use of the electroplating bath

Description:

Every 6 months a new electroplating solution is made of 1000 litres water, 150 kg ZnO, 200 kg ZnCN, and 40 kg NaOH and 5 litres of brightening liquid (Monocol containing ZnCN, NaCN, NaOH). After a while fresh electroplating liquid of the same composition is added to the bath. The amount added is estimated by measuring the decrease in solution level.

Options:

Good house keeping measures could save fresh electroplating solution, for instance by letting the electroplated object dripping above the electroplating bath before rinsing.

Investigation is needed to conclude whether the recept used to make electroplating solution is the most effective. Information on low cost solutions is available from suppliers of chemicals, companies in the same branch, or by letting a student do an investigation.

Measuring the concentration of the used chemicals could reduce cost. The electroplating division of Tazara Workshop uses less chemicals when preparing the bath and also when upgrading the solution. Tazara Workshop offered to analyse samples from the electroplating bath. Some samples have indeed been send to Tazara but Tanzania Cyclebells Manufacturers were not satisfied with the cooperation because analysing took to long or was not carried out at all. Each half year the old electroplating solution is discharged to the sewer. The bath might last longer if the solution is upgraded according to laboratory analyses rather than estimation. Therefore, better communication with Tazara Workshop could improve the production at Tanzania Cyclebells Manufacturers.

If the good house keeping and laboratory analysis can improve the use of the electroplating bath such that only 2 times per month solution has to be added instead of 4 times than 10 litres of water could be saved each day.

3) Reusing rinsing water

Description:

Per day the company uses 1,000 litres of clean water for rinsing.

Option:

It is not always necessary to use clean water for rinsing. Especially for rinsing of relatively dirty objects water can be reused, for instance after derusting or first rinsing after electroplating. In this way it must be possible the reuse 50% of the rinsing water. This safes 500 litres of water per day (18 TSh/day). No investment costs are necessary since storage tanks are available.

4) Services provided by the Small Industries Development Organisation (SIDO)

Description:

The relation with SIDO is not very good since the enormous increase in rent. At the moment SIDO does not provide training or other services.

Options:

Of the 14 metal workshops which are operating on the SIDO site 4 do electroplating. This should be an argument to ask SIDO to organize specific training and information in this field. Interesting fields for Tanzania Cycle Bells could be; new electroplating techniques, use of chemicals, and especially the handling of waste.

5) Information from the Ministry of Labour

Description:

The managing director Mr Mgunda has been to a seminar organised by the Ministry of Labour once. This Ministry gave some information on safety but not convincingly since the cover over the acid bath was never installed. Guidelines for handling chemicals and wastes could really improve safety of the workers.

Option:

The management could ask the Ministry for information on handling chemicals and wastes and other safety issues.

6) Water supply

Description:

The National Urban Water Authority (NUWA) estimates the water use to be 31.8 m^3/months. According to the waste audit 30.6 m^3 /month is used. The company pays 1,150 TSh monthly (≈1.9 US$/month). Therefore NUWA charges 36 TSh/m^3 (≈0.06 US$/$m^3$) the rate for domestic users, the official rate for industries is 145 TSh/m^3 (≈0.24 US$/$m^3$).

Option:

As the cooperation with the NUWA seems good the company could ask for information on efficient water use.

7) Being aware of the sewerage regulation

Description:

No direct payments are done to the Dar es Salaam Sewerage and Sanitation Department. Possibly the payments are included in the water bill or done by SIDO. The company is not aware of effluent characteristics neither of effluent standards. Estimates of the Rapid Assessment indicate that Tanzania Cycle Bells discharges more zinc, cyanide, and chromium than allowed. Other electroplating companies also exceed the effluent standards. The chemicals discharged can inhibit the biological treatment of the waste stabilization ponds.

Options:

The company should check if payments for the sewerage services are done. Furthermore measurements should be done to indicate whether the effluent is conform the standards.

Table 15: Estimated effluent characteristics (Economopoulos 1993, Gazette 1983, appendix 7).

		Zn mg/l	CN mg/l	Cr mg/l	NaOH mg/l	F mg/l	Oil mg/l
Tanzanian Standard		*1*	*0.2*	*0.2*		*8.0*	*20*
Cyclebells	Degreasing						4.8
	Electroplating bath	6.9	15		50		0.5
	Blue Passivation	16		3.3		7.5	

5.3 Waste oil

Waste oil disposed to the sewer will negatively influence the performance of the waste stabilization ponds, as oil concentration above 50 mg per litre inhibits the biological treatment processes (Economopoulos, 1993). In Dar es Salaam 5,547 tonnes of lubricating oil are used each year. There is no collection system for waste oil. As result most oil ends up in the sewer or directly in the environment. Among the industries discharging to the Vingunguti waste stabilization ponds most oil is used in car maintenance and in the metal sector.

The 11 car maintenance companies have a total estimated waste oil volume of 119 m^3/year. If all oil would be discharged to the sewer, the waste water of the car maintenance sector would have an average oil contents of 5 mg per litre.

Oil refreshing:
5 litres of waste oil per car
100 cars per months
500 litres oil / months discharged to sewer.

The company is willing to pour the waste oil in a provided tank if the oil is collected for reuse.

Box 8: Deawoo Motors.

None of the car maintenance companies had a good solution for the waste oil disposal. Some discharge the oil to the sewer, other might spoil it on the ground. Some of the companies have their workshop connected to the storm water sewer which flows to the sea-outfall in the harbour. This implies that not all the oil discharged to the sewer reaches the Vingunguti WSP. But shock loads might occur.

With small effort the waste oil could be reused. Waste oil produced at BIMA Motors is used by the employees in pit-latrines to prevent smelling. An other example of informal reuse of waste oil is happening at Tasia. This company manufactures car springs and uses oil to cool the springs when leaving the oven. The oil bath is cleaned out once a year. The used oil is sold for wood preservation (200 litres for 400 TSh). Another company reusing oil is the Tazara Workshop where waste oil produced and collected in the Workshop is burned in their own furnace. Waste oil coming from the locomotive during washing is not recovered and flows to the sewer.

The Tanzanian Petroleum development Cooperation (TPDC) invested the possibilities for rerefining waste oil (Mpande, 1993). Estimated is that 20% of the used oil is collectable, which would amount up to 1109 tonnes in Dar es Salaam. Most waste oil is only contaminated while oil and additives are still intact. Rerefining is possible with different techniques. The acid clay technique is relatively simple to design and operate but enormous amounts of wastes are produced. More advanced technologies based on vacuum distillation and hydrogenation are more capital intensive and large amounts of waste oil should be collected to make the technology affordable.

BP has started a pilot project to collect 500 to 600 tonnes waste oil per year. BP placed waste oil collection tanks at some of their larger consumers. Industries in Vingunguti area included in this project are D.T. Dobie, Scania, and Tazara. The collected oil will be mixed with furnace oil to be burned at the Twiga Cement factory at Wazo Hill. BP is in discussion with the government to motivate the public and industry by stricter legislation.

5.4 Waste water prevention options in industry

The insufficient water supply forces the industry to prevent water from being spoilt. Still many options for waste water prevention are present. Zahra Bottlers could prevent the production of almost 1,500 m^3 waste water per year. This is less than 1 % of the Vingunguti waste stabilization pond influent. A limited decrease of waste water flow to the ponds can be achieved from waste water prevention in industries. The electroplating companies can reduce the discharge of chemicals like: zinc, cyanide, chromium, and copper. The metal product manufacturers and the car maintenance companies can prevent the discharge of waste oil. These compounds can inhibit the biological treatment process of the waste stabilization ponds resulting in poor performance. Furthermore clean water is a scares resource and thus saving is important.

6 Institutional framework

The government plays a major role in environmental protection. An institutional framework which is functioning well should be able to stimulate industries to make their production more and more environmentally sound. The waste audits resulted in waste water prevention options which are economical attractive. However several of these options will not be implemented as long as information, control and regulation from the responsible institutions is absent.

In Tanzania environmental institutions have not yet developed to an effective institutional framework. In the Netherlands the environmental sector has reached a certain stage of maturity after interesting developments during the last decades. The first paragraph of this chapter will discuss the successes and failures of the Dutch environmental institutional framework, which can serve to compare and assess the Tanzanian setup. Thereafter the Tanzanian policies, institutional setup and legislation will be discussed. In the last paragraph recommendations to improve the Tanzanian institutional framework will be made.

6.1 The Dutch institutional framework

Dutch policies

In 1970-72 environment became an independent aspect of governmental management. Environmental problems were looked at as classifiable per sector, foreseeable, bound to certain locations, technologically solvable, and especially as a threat to public health. Environmental policies were grouped per compartment (air, soil and water) and the government as main actor practised imperative management. This management strategy appeared to be ineffective, as evaluation showed that 60% of the companies were operating without the permit required by the law. The lower governmental institutions responsible for regulation and control lacked capacity and motivation to fulfil their new task. Another cause of the ineffectiveness was the fact that companies did not fear the sanctions, and did not follow the rules set by governmental authorities. As reaction the government started to practise an even more stringent management.

With time the idea behind the environmental management changed from securing public health to sustaining ecological quality to reach sustainable development. People realized that the environmental problems are complex and coherent. The grouping per compartment seemed no longer useful as problems are complex and coherent. A more integrated approach was needed. Therefore policies were being grouped by theme: acidification, eutrophication, distribution, elimination, disturbance, dissipation, wastage, and climate change.

The capabilities of the government to solve the environmental problems appeared to be far less than expected. As a consequence the management strategy was revised, the instruments were diversificated, and the organisation restructured. This resulted in deregulation, *changing from juridical to more economic and communicative instruments*. A new organisation structure focused on target groups and regions. And policies were based on general guidelines with projects covering specific problem area's.

Consulting target groups was a must as the polluters had best insight in possibilities for pollution prevention. To make these consultation successful the government accepted the target group as equal. The target groups in their turn had to take their responsibility and contribute to a more sustainable development. This way the environmental policy developed towards self-regulation in between a framework set by the government.

Waste water policies developed according these above described trends. At first the government aimed at reducing water pollution by establishing treatment plants and regulating discharge. However most effect was accomplished when the polluters were given the responsibility within a stimulating framework to stop polluting.

Water has always played an important role in Dutch history. Institutions responsible for water management were established in the early middle ages. Since 1950 some of these institutions called Water Boards, took responsibility for water quality control including purification of waste water. In the fifties the surface water quality had reached a dramatic low point, some waters had turned into open sewers. At that time pipes were used to transport waste water to larger surface waters, as solution to local inconvenience. In the sixties the government resolved to increase waste water treatment capacity within 20 years such that the surface waters would no longer be polluted. Finally it took about 25 years to reach this goal.

In 25 year the total BOD discharge was reduced to less than 7 million inhabitant equivalents, a reduction of 80% (Ministerie van Verkeer, 1995, p290,293, inhabitants equivalents see note page 45). Common waste water treatment technologies used in the Netherlands are the oxidation ditch and the activated sludge process. In 1995 97% of household and industries are connected to a sewer leading to a biological treatment plant. Most sewers (74%) mix waste water with rain water. In times of heavy rainfall untreated sewerage water must be discharged as the treatment capacity is too low. These discharges are major contributors to surface water pollution (10-20% BOD, Zinc and Lead > 30%, Ministerie van Verkeer, 1995, page 288). Therefore hardened surfaces will no longer be connected to the regular sewer in future. This will also contribute to a higher ground water level.

Other aspects that are given special attention are eutrophication, heavy metals and organic micro pollutants. For eutrophication the target is to reduce the phosphate and the nitrate discharge by 75% by 1995 respectively 1998 (baseline 1985). Important measures to reach the target are: process (fertilizer industry) and product changes (phosphate free detergents) and tertiary treatment of waste water and balanced manuring. For nitrate the target will probably be reached by 2005 as there are some planological problems. Reduction of the discharge of heavy metals was realised by waste water treatment, product and process changes (unleaded petrol, alkali, pesticide, fertilizer, metal, leather industry and others). The target to reach a 50% reduction by 1995 (baseline 1985) was not realized as the discharge from diffuse sources is difficult to reduce (diffuse sources are atmospheric deposition, (waste) water from hardened surfaces, agriculture, households and others). An international agreement was made to banish the discharge of micro organic pollutants.

Dutch institutions

Important institutions active on **national level** in the Netherlands are:

The *Ministry of Traffic and Public Works* is responsible for overall water management. Implementation is decentralized to the regions except for the main waterways which are managed by the State. The Ministry works in cooperation with the *Ministry of Housing, Spatial Planning and the Environment,* among other things responsible for water supply, and the *Ministry for Agriculture, Nature Conservation and Fishery.*

In 1920 the *State Institute for Integrated Fresh Water Management and Waste Water Treatment (RIZA)* was established to investigate and advise on waste water treatment. Later on water quality management became another task of this institute. As such advice is given on granting permits to important industrial sectors.

The *Commission Implementation Law Polluting Surface Waters (CUWVO)* was established to improve coordination and consultation between the governmental institutions involved in water management. Recently the task to improve integrated water management has been given to this institution.

Then there is the *Foundation Applied Research on Water Management (STOWA)* in which all institutions involved in water quality control are represented. This foundation stimulates research on surface water, ground water and waste water.

On **regional level** the following institution are active in the Netherlands:

The *Provinces* are responsible for regional water management. Mostly this responsibility is delegated to *Water Boards.* These Water Boards have been controlling water quantity since the early middle ages. Nowadays they are also responsible for water quality and purification. In some regions Water Boards were too small for this new task and separate Purification Boards were installed covering a larger area. In all regions the *City Council* remained responsible for the sewerage system up to the treatment plant which is managed by the different Boards.

An advantage of the Water Boards as responsible institution for purification is the fact that no political or managerial judgements have to be made by this institution. All money collected through impositions will be used for purification of waste water. Inhabitants, house owners, land owners and companies all pay leges to the Water Board, in contradiction with the City Council which collects leges only from those who are connected to the sewerage system. Even if the Water Board does not treat the waste water in a particular area inhabitants still have to pay, because untreated discharge is made possible by a good water quality sustained by treatment in other area's.

An other advantage is the combination of passive (permits) and active (building treatment plant) management of water quality as these tasks rely on the same capabilities.

Control and enforcement of the existing laws is done by civil servants of the State Environmental Inspection, Inspectors of the Province, of the Water Board, or by the normal police force. These servants are allowed to take samples and preform measurements, and to enter the company, to have insight in the administration.

Dutch legislation

In Dutch environmental legislation there are general laws addressing procedures and management issues, like the Law Environmental Management (Wm) and the General Law Management (Awb). Furthermore there are laws dealing with specific subjects like the Law Polluting Sea Water (WVZ) and the Law Polluting Surface Waters (WVO). This last law plays a major role in preventing water pollution.

Water pollution:

In the nineteenth century public health inspectors in the Netherlands noted that legislation on waste water disposal would improve public health. In 1952 the *Nuisance Act* was changed such that waste water problems could be addressed in certain cases. But due to lack of capabilities, control and enforcement this had little impact.

Discharge of effluents:

Finally in 1970 the *Law Polluting Surface Waters (WVO)* came into force. This law prohibits direct discharge of waste water without a permit. Certain industries also need a permit for discharge of waste water to the sewerage system (indirect discharge). There are also sewerage regulations which apply to these indirect discharges.

This law implies that the polluter has to pay. Households and small industries pay a fixed rate, while larger industries pay according to their discharge. The imposition is based on the average chemical oxygen demand per 24 hours of the waste water discharged, expressed in inhabitant equivalent*. For other specific compounds the unit of weight per imposition year is used as basis for the imposition. As it is expensive to preform measurements waste water coefficients were used to classify industries but this system became to complicated due to the large number of different processes. As no appropriate coefficients for certain sectors could be set, more and more companies had to preform expensive measurements. Therefore a new classification system based on water use with a reduced number of groups will be introduced. Such that only a limited investigation will be needed to classify companies.

Control and enforcement:

Water quality control is based on standards. The Dutch standards are based on international agreements like the International Rhine Pact, European Guidelines etc.. An important guideline is the classification of compounds on the black, grey list. Discharge of compounds of the black list must be stopped, using the best available technology. While discharge of compounds of the grey list must be reduced with the most appropriate technology. Temporary limits were set for a minimum water quality on the short term. Targets were set for improving water quality on the long term.

All discharges must be conform the standards as written down in the law regardless the permit. If discharges are not conform the standards or the permit can lead to a recognizance, the permit can be withdrawn, and the judge can even decide to take the company out of production.

Inspectors are allowed to take samples and perform measurements. Furthermore industries must have an internal environmental management plan in which waste water flows are registered.

Industries reduced their waste water flows by changing the process, realising treatment facilities, or in the worst case by closing down the factory. These measures were cheaper than paying the impositions. As such impositions were effective instruments to reduce water pollution. Permits, however resulted in a long lasting fight between government and industry about historical attainments and about what could be discharged and what should be purified (Vereecken, 1994, p145). Together this resulted in a reduction of industrial waste water from 33 million inhabitant equivalents* in 1970 to 10 million inhabitant equivalents in 1995.

*Note: The equation to calculate inhabitant equivalent is: i.e. = (Q/136)(COD+4.57N) in which Q is the waste water flow in m^3/day, COD is the chemical oxygen demand in g/m^3, N is the concentration of organic and inorganic nitrogen in g/m^3, and the factor 136 expresses the oxygen demand of the average waste water produced per person per day (Deventer 1990).

6.2 Tanzanian institutional framework

Tanzanian policies

The United Nations declared the International drinking *Water Supply and Sanitation Decade* for 1981 to 1990. The objective was to enhance the role of the government in assisting all communities to have safe and adequate water supply and sanitation services by the end of the Decade. The Decade brought a development towards more cost effective approaches. But the objection was not met as at the end of the Decade less than 44% of the rural population was served. The targets were revised to: water for all by 2002 and safe sanitation facilities for 95% of all households by 1997, and health for all by 2000 (Ministry Water 1992, p24).

In the water and sanitation sector many different organizations are active, like external support agencies, non governmental agencies, private companies etc.. Efforts of the ministry to coordinate the activities have not always been successful. As reaction on the ineffective operation of governmental organizations, some external support agencies turned to grass root level without going through the government hierarchy. Others turned to institutional support to maximise the available resource or to integrated approaches in stead of the specific project approaches. Furthermore the world economic recession set in a trend of reducing the amount of foreign aid to Tanzania (Ministry Water 1992, p21).

As response to the economic crises in Tanzania several economic programmes were launched during the 1990's. As these programmes did not include social services the sewerage and sanitation problems increased. To reverse this trend the *Economic and Social Action Programme* was put up to find funds for improvement of social services, including water and sanitation (Ministry Water 1992, p28).

At this time the *first national water policy* was endorsed with the objective to:

- provide clean and safe drinking water within easy reach as a first priority and then satisfy after needs for other users;
- optimise use of the limited water resources;
- equal priority to be given to both urban and rural water supplies and;
- improving all urban water supplies and establish efficient customer services.

In the last decade the water and sanitation services provided were still below expectation. A main constraint was the ineffectiveness of the different institutions involved. This lead to the start of two institutional strengthening projects:

1. The institutional restructuring project to set up autonomous self financing *Urban Water Supply and Sewerage Authorities*. This authorities under the Ministry of Water would be responsible for the management of water supply and sanitation facilities in a specific urban area.

2. The *Urban Sector Engineering Project* aims to upgrade and extend the infra structural services in urban area's. This is a project financed by the World Bank concerning the infrastructure of nine towns: Dar es Salaam, Tanga, Moshi, Arusha, Mwnaza, Morogoro, Iringa, Mbeya and Tabora. Water and sanitation will be included in this study (Ministry Water 1992, p41).

In 1995 the water targets were again revised. For water supply the target changed to 90% urban coverage, instead of 100%, by 2002. For rural water supply two stages are defined, first all villages should have a reliable water source within a distance of three kilometres. Second 70% of the rural water supply coverage will be achieved within a walking distance of 400 metres of all households. The original target was to provide water for all by 2002.

Policies clearly define that water supply comes before sewerage and sanitation. Such priority setting is understandable as water supply is insufficient. But uncontrolled discharge of waste water threatens health and environment. Especially in the rapid growing urban area's waste water disposal is an urging problem.

As policies focus on water supply the sanitation target is unclear. The sanitation and health target are improved sanitation for 95% of the households by 1997 and health for all by 2000. But no specification of improved sanitation is given and a detailed overview of present sanitation facilities is lacking, making the target meaningless. Clear targets based on the evaluation of the present situation must be set concerning urban and rural sanitation and industrial waste water treatment.

Tanzanian institutions

Important institutions active on national level in Tanzania are:

The *Ministry of Water, Energy and Minerals,* the highest institution responsible for water resource management. The roles of the ministry are policy and strategy development, coordination, regulation, supervision, monitoring and evaluation. Implementation is decentralised to regions and districts, except for large projects. The water division of this ministry is divided into four sections; Water Research and Design, Construction and Material Testing, Operation and Maintenance and Water Laboratories, and the Sewerage and Drainage section.

This *Sewerage and Drainage Section* concerns itself with sewerage and low cost sanitation. Large projects concerning construction and rehabilitation of the sewage systems in Tanzania are implemented and financed by this section. After the project the sewerage system is delegated to the sewerage department of the responsible city council.

Important institutions under the Ministry are *Central Water Board*, which is responsible for the Water Rights, and the *Tanzanian Technical Standards Effluent Committee*, responsible for setting the effluent standards.

The Ministry of Water, Energy and Minerals cooperates with the *Ministry of Industry and Trade*, as industries are the major consumers and polluters of water. Many industries are producing under capacity because of inadequate water supply. The *Tanzania Bureau of Standards* (TBS) under the Ministry of Industry and Trade is responsible for setting an controlling standards for product and production processes.

Furthermore cooperation with the *Ministry of Tourism, Natural Resources and Environment* is important as this Ministry plays a major role in the overall water cycle balance. The Division of Environment is preparing the National Environmental Policy.

Another important institution on national level is the *National Environment Management Council (NEMC)*, which was created to act as an advisory body to the government on all matters relating to the environment. As part of its advisory capacity, NEMC is given the duty to formulate and recommend policy, coordinate activities, evaluate and improve existing policies, stimulate public and private participation in programmes and activities for national beneficial use of natural resources, specify standards and norms, establish and operate a system of documentation, formulate proposals for legislation, establish and maintain liaison in other national and international organizations, and undertake general environmental education programmes.

Important institution on Dar es Salaam level are:

The responsible institution for water supply, *the National Urban Water Authority (NUWA)*, a parastatal under the Ministry of Water, Energy and Minerals. The Authority was created with the objective to manage all urban water works in the country. But in practise the Authority is only managing the water supply in Dar es Salaam. The water supply in Dar es Salaam is below expectations as the supply is insufficient, the treatment plants are under-utilized, the quality of the treated water is unsatisfactory, and much water is lost through leakages in the distribution system. Lack of funds resulted in inadequate maintenance, lack of spare parts, and delayed investments needed to serve the growing population of Dar es Salaam.

The Vingunguti area is a low pressure area because of high water demand in the city and the fact that the area is situated a bit higher. Water is supplied from the Lower Ruvu water treatment plant. NUWA decided to upgrade the water pressure on Tuesday and Saturday by injecting water from the Upper Ruvu water treatment plant. This decision was made without consulting the industries of which some are not operational on Tuesday due to electricity load switching. Plans to rehabilitate the water supply system will be implemented as soon as funds are made available. Therefore only on longer terms water supply to the Vingunguti area will be improved.

The industries pay either 611 TSh per 1000 gallon (0.145 TSh per litre) or 33,350 TSh per month, a minimum tariff for unmetred industries in low pressure area's. Since this special tariff is a flat rate it appears at disadvantage to small water users. Therefore some industries refuse to pay or ask for installation of a water metre or ask to be disconnected. Whereas large water users may feel no need to reduce their water consumption.

The regional institution responsible for sewerage and sanitation is the *Dar es Salaam City Council*. In general, Dar es Salaam City Council's functions, power and responsibilities are ill-defined. The Council is over-staffed, under-funded and under-resourced. Staff are very poorly paid and obliged to supplement their income. Therefore the functioning of the Council is ineffective, inefficient, lacking accountability and does not respond to local needs (DEVCO, 1993).

One of the 13 departments of the Dar es Salaam City Council is the *Dar es Salaam Sewage and Sanitation Department (DSSD)* which is responsible for the operation and maintenance of the Dar es Salaam sewage system.

The City Council decides on the tariffs DSSD may charge for sewerage services. These tariffs are based on what people want to pay rather than on real costs. While investigation indicated that people are willing to pay more for better services (Mujwahuzi, 1993). Revenues are collected by NUWA and DSSD. Only for domestic users the collection of revenues is combined in one payment. NUWA can disconnect the water supply if people fail to pay for the water supply or sewerage services offered. Industries and institutions pay NUWA and DSSD separately.

Limited collection of revenues is the result of the incomplete registration. During the data collection for the Rapid Assessment 44 industries stated to have a sewer connection. Only 10 companies were registered as payers of revenue at DSSD. For 2 companies the actual amount of revenue paid could be found. Those two were registered by NUWA.

The sewer connections are registered by DSSD. The registration started in 1992 earlier connections are not registered and hence unknown. Only 3 companies were registered to be connected to Vingunguti waste stabilization ponds.

DSSD is also responsible for monitoring. But very little measurements are done, probably due to lack of equipment, chemicals, manpower and money (analysis summarized in appendix 6).

DSSD has a special department for emptying pit latrines. But very little data on the activities is available. There is no registration of the number of vacuum tankers dumping at Vingunguti neither the origin of the waste is registered. One of the reasons for this is that only 25% of the dumping at the waste stabilization ponds is done by DSSD. Many other companies are active in the field of pit latrine emptying. The Health Department, Malaria Project, Harbour Authority, National Bank of Commerce, Tanesco, Tazara, and some private companies have their own vacuum tankers.

There are several reasons why the present institutional set up results in an ineffective water management. The sanitation sub-sector is disintegrates among different institutions and the coordination between them is weak. Similarly demarcation of responsibilities is unclear leading to duplication or forthcoming of effort and scattering of scares resources (Ministry of Water, 1995).

Furthermore the functioning of different institutions is frustrated by the lack of power or capacity. For instance DSSD responsible for the sewerage system in Dar es Salaam is empowered to collect revenues but is not empowered to set the tariffs or to block the sewer in case no payments are made. DSSD lacks capacity to function well as funding is inadequate and little equipment is availably and spares are too expensive.

Institution:	Empowerment:	Capacity:	Accountability:
Sewerage Department of City Council (DSSD)	-	-	+
National Urban Water Authority (NUWA)	+	-	+
Sewerage and Drainage Section of Ministry (DSD)	±	-	±
Bureau of Standards (TBS)	±	±	-

Box 9: Reasons for the present functioning of institutions responsible for waste water treatment and water supply.

The NUWA, responsible for water supply, has the power to disconnect the water supply in case no payments are made. Mainly lack of financial resources makes the functioning of this institution ineffective. Both DSD, under the Ministry of Water, Energy and Minerals, and TBS, under the Ministry of Industry and Trade, are functioning better. Both institutions are empowered to take surprise sampling at industries. DSD is responsible for waste water control. Few investigation were made concerning the amount of waste water and the destiny of the waste water (Ministry of Water, 1988). TBS visits industries to control whether those are producing according to their standards, for instance food and beverage industries are visited four times a year. TBS controls the quality of the products not the waste water discharged.

An overview of the factors frustrating the functioning of these four institutions is given in box 9. As result water supply is inadequate and waste water discharged uncontrolled. The polluter pays principle is undermined by the lack of control.

As the present institutional structure is a major obstruct to execute water and sanitation services effective reform is required. At presently there are projects to strengthen the Dar es Salaam City Council and to combine sewerage and sanitation services in one self financing Urban Water and Sewerage Authority. In Dar es Salaam NUWA and DSSD and DSD (Maji Ubungo - part of the Sewerage and Drainage Section of Ministry of Water) would be combined to form such an authority.

Combination of DSSD and DSD will give little problems as the institutions are closely related. However combing water supply and sanitation in one institution asks for a clear strategy to make sure that sewerage works are not neglected, as focussing all attention on improving water supply seems to be more rewarding on short terms.

Making the institutions self financing will result in higher charges for the services as the charges are unrealistic low at present. But a rise in charges will certainly affect the poorest people. And will not be accepted by the costumers unless better service is ensured. For water supply this will mean the amount of water supplied must increase. Another important aspect is the billing system. Costumers want a clear and correct water bill. Therefore water metres will have to installed. The installed water metres will make costumers aware of their water use and will motivate them to prevent water from being wasted. Better services concerning sewerage systems will mean extension for those not yet connected. The ones already connected must be informed about sewerage regulations. Samples must be taken to see wether the effluent is conform the standards. The industries must be informed about waste water prevention and waste water treatment. Also for sewerage services a clear and correct billing system will be required.

Both projects focus on restructuring and self financing. For the people presently employed in the water and sanitation sector the restructuring will probably mean that they will be doing the same job in another environment if they are not fired. More changes will be necessary to motivate the people. Time and money must be invested in better salaries, training, better and more equipment, setting up administration etc.. Therefore a lot of work has to be done before the institutions can be self financing.

Tanzanian legislation (Agenda, 1995)
Tanzania has four specific laws concerning water (box 9). But also several other laws are relevant if it comes to waste water. Therefore legislation will be discussed per theme.

- Water Utilization and Control Act, Amendment and Regulations
- Urban Water Supply Act and Waterworks Ordinance
- Public Health Sewerage and Drainage Ordinance
- Tanzania Bureau of Standards Act

Box 10: Tanzanian water laws.

Water pollution:

Issuance of *Water Rights* (the right to divert, dam, store, abstract and use water) also serve the function of assisting the government in regulating water pollution. In addition to the main laws, several other laws help to achieve this function. Like the *Water Utilization Control Act* which implies that Water Rights should not be granted unless the applicant has the ability to meet pollution standards. Specifically the Water Utilization Control Act requires that ' precautions be taken to the satisfaction of the Water Officer to prevent accumulation in any river, stream or water course of silt, sand, gravel, stones, saw dust, refuse, sewerage, sisal waste or any other substance likely to affect injuriously the use of such water'.

Discharge of effluents:

Standards are established under the *Water Utilisation Control Act* for effluents and receiving waters and it is an offence not to abide by these standards before and during discharge into water courses, receiving water or sewers. If a Water Right is granted for industrial purpose, the following narrative standards apply:

- the user shall return the water to the same body or an other water body as authorised by the Water Officer;
- the user shall return the water substantially undiminished in quality;
- the user shall not pollute the water to the extend of directly or indirectly causing injury to public health, livestock or fish, crops, orchards or gardens which are irrigated by the water, or any product which uses the water in its production process;
- user shall treat the water to meet the water quality standards specified below.

No discharge from commercial, industrial, and trade waste systems is allowed within 230 metres of a borehole, well or other water body. No discharge from these sources is allowed into receiving waters without a 'consent' granted by the Water Officer. The public has the right to object to granting of a 'consent'. In practise however, issuance of a Water Right is deemed to be a consent and no separate consent requirements exist.

Tanzania Bureau of Standards (TBS) has general standards for sewage effluent and evaluation. The Water Utilisation Control Act establishes two sets of standards for effluents, one for direct discharge into receiving waters, another for indirect discharge via municipal treatment works. These standards are listed in appendix 7. These standards are given in concentration while for certain compounds it is useful to set standards in unit of weight per unit time. Otherwise industries can discharge the waste water diluted. To make standards useful the description should include a test value (0.4 g Cd per litre water), the appearance form of the compound (total, dissolved, associated with suspended solids), a testing procedure (the number of measurements taken over time or place that should exceed the test value in order to be representative). For certain compounds the method of analysis should also be described (Ministrie van Verkeer, 1995, p126).

Monitoring of performance:

Several provisions of laws relate to monitoring of performance. For example it is required that 'returns' (reports) are made by the Water Right holders to the Water Officer setting out the nature of wastes or effluents provided by his use of water. The Water Right holder shall also install or facilitate the installation at the point of discharge of all machinery and other facilities necessary for the taking of samples and the collection and treatment of effluents. In addition, the Water Officer is given powers to require submission of 'information' from holders of Water Rights, and may enter and inspect any premises. Surprise sampling is carried out by the Laboratory Division at Maji Ubungo (DSD- part of the Sewerage and Drainage Section of the Ministry of Water, Energy and Minerals) and includes sampling, analysing, checking water upstream and downstream of the effluent point. The Tanzania Bureau of Standards has also prepared several standards for sampling methods for industrial effluents. This Bureau is responsible for product specifications and process standards and may also make surprise inspections.

Enforcement:

Where a Water Officer finds a *Water Right* holder to be in violation of the standards or condition of the Water Right, he may serve a notice of 'default' on the Water Right holder, giving the holder an opportunity to rectify the default. If no improvement occurs within the specified time, the Director of Public Prosecution may prosecute the Water Right holder in court for an offence under the relevant act. In addition the Water Right may be revoked or diminished for failure to comply with the conditions of the Right. Penalties contained in the Water Utilisation Control Act are recently increased.

The *Penal Code* applies the polluter pays principle to require violators to clean the polluted water within a reasonable period at own expense.

The *National Industries Licensing and Registration Act* also regulates the by-product of industry, such as water pollution. This Act is intended to provide registration and regulation of industries in Tanzania. The Act applies to industries which are defined as any factory which employs more than 10 workers on any day. The Act divides industries in two categories for purpose of regulation: small-scale and medium-and-large-scale industries. Small scale industries are required to obtain a Certificate of Registration in order to establish an industry. Large and medium sized industries are required to acquire a licence, from the Industrial Licence Board. First a Temporary Industrial Licence is granted for three years in which the industry is monitored and must submit progress reports each year. After an inspection by the Ministry for Industries a Full Industrial Registration License may be granted. For with potential pollution problems the National Environmental Management Council (NEMC) is consulted to give assessment, advice and recommend measures to be taken.

In practise industries are registered by the Ministry of Industry and Trade but they are not aware of sewerage regulations or environmental legislation. Institutions abdicate responsibilities, shared responsibilities are not executed at all, and waiting on an advise by the NEMC is another excuse not to act. In 1995 the Ministry of Water, Energy and Minerals stated that the handling of sewerage and sanitation issues was unsatisfactory due to lack of sustainable legislation and laxity in the enforcement. But few complaints about the existing legislation are formulated. The major point is that legislation should be adapted to the changing institutional set up. Therefore the major problem with legislation seems to be control and enforcement.

Penalties described in the different laws are generally low. Instruments like environmental impact assessment and environmental taxes, have to be embedded in legislation which will take time. As the government needs money to address environmental issues the polluter pays principle seems the most useful instrument at the moment. Furthermore participation of citizens is important but successfulness as a policy instrument will differ with the various subjects.

6.3 Possibilities for improvement

Environmental management in based on three aspects:

- *Communication*, to create awareness.
- *Rules of conduct*, to stimulate change of behaviour.
- *A legitim steering institution*, to set and control rules of conduct (Glasbergen, 1994, p16).

In the Netherlands the institutional set up has been formed by historical developments. At present integrated water management is complicated by the large number of institutions active in this sector. A special committee (CUWVO) has been established to coordinate the different governmental institutions. The dialogue between government and polluters, in the form of target groups, has been set up as one realized that the traditional management failed. As such communication was recognized as an important aspect in prevention of water pollution.

The government has always been the legitim steering organization in Dutch environmental management. The rules of conduct have changed towards self regulation within a framework set by the government. The polluter pays principle combined with a permit system forms a useful instrument.

In Tanzania the environmental management has not yet leaded to an effective institutional framework. Public health is still a major aspect. Therefore water policies tend to focus on water supply rather than on waste water treatment. However in densely populated and industrialized area's waste water treatment is a important issue. The present institutional set up is not functioning due to a lack of communication and resources. Communication between the different institutions and with water polluters is lacking. The same accounts for control and enforcement of environmental laws. The combining of different institutions into one autonomous institution will be a first step towards a more functional integrated water management.

Most of the companies are not aware of environmental legislation, problems, and responsibilities. Resulting in enormous pollution of water, air and soil. There are only few companies which are aware of environmental problems and take full responsibility (for instance Tanzania Breweries). Governmental interference is necessary to protect the environment. Therefore the restructured institutional set up being realized presently, must be combined with a clear policy and appropriate instruments. Such policy should be based on the following elements:

- The polluter pays principle, to pass full costs to the ones responsible for pollution,
- Water quality objectives, to protect and improve receiving waters in an effective way.
- Receiving water quality standards, to indicate the 'acceptable' waste load under particular circumstances.
- Emission standards, to ensure that pollutant concentrations in receiving waters do not exceed the critical levels (Abel 1989, p 173).

Note that in absence of additional regulation, the 'polluter pays' principle can lead to the inevitable idea that pollution is a right which may be exercised by anyone who is willing and able to pay the appropriate charge. In the Netherlands, Britain and other countries additional regulation is realised through a permit system, then discharge is forbidden except with a permit. If limits are exceeded fines and penalties are imposed and payments have to be made for restoration of any damage caused by the illegal discharge.

In the Netherlands receiving water quality standards are only used for compounds with a relatively low pollution potency like: sulphate, chloride and heat. For other pollutants emission standards are used. Tanzania uses emission standards. The polluter pays principle combined with an additional permit system are not yet developed, but could form an effective instrument in prevention of water pollution. Water quality objectives for specific watersheds or compounds could be a useful instrument in (inter) national water management.

7 Conclusions

7.1 Methodology

In this investigation an upstream approach was used. Combining different methods like the Rapid Assessment Method to indicate the waste water characteristics like flow and BOD, the Waste Stabilisation Pond Design Method for Eastern Africa to re-dimension the ponds, and Waste Audit Method to identify waste water prevention options in industry. This methodology appeared to be very useful to investigate a 'waste stabilization pond watershed'. However specific problems were experienced with the Rapid Assessment;

- Differences between the waste load factors of the two editions of this method.
- Differences between waste water volumes calculated with the Rapid Assessment and the volumes stated by the companies on the questionnaires are very large, up to a factor 28 for the vegetable oil factory. As result of the water shortage in the area industries may use less water than under normal conditions. But in case of the oil industry assumptions made in the Rapid Assessment concerning process and operation may not be appropriate for this particular factory.
- The Rapid Assessment does not account for companies with a relatively small water polluting potention. However as the waste stabilization pond investigated is only a small water shed the contribution of such companies is not negligible. To account for such companies in this investigation assumptions have been made.

This makes the results of the Rapid Assessment very inaccurate. Measurements are needed to indicate whether the Rapid Assessment waste load factors are appropriate for Tanzania. The Rapid Assessment Method would be more useful if more information about the assumptions made to obtain the waste load factors is given.

7.2 Performance of the waste stabilization pond

The Vingunguti waste stabilization pond design was not appropriate for the operation under present conditions. The reason for this is the estimated BOD loading, rather than unadapted design formula's. This BOD loading was based on a fictive population. The present operation of the Vingunguti waste stabilization ponds is below expectations. And the ponds will be unable to cope with increasing waste water flows that are expected for the future. A limited decrease of waste water flow to the ponds can be achieved from waste water prevention in industries. Industries can prevent the discharge of compounds which affect the performance of the waste stabilization. These compounds may affect the quality of the effluent and sludge, making these products unsuitable for agricultural use.

The present institutional setup is a major obstruction to execute water and sanitation services effectively. The poor maintenance and operation, as well as the absence of control and enforcement of environmental laws affects the performance of the waste stabilization ponds.

7.3 Making the waste stabilization pond technology appropriate for Tanzania

To make the waste stabilization ponds appropriate for future use the responsible institutions must be restructured and strengthened to investigate and rehabilitate the ponds, to improve operation and maintenance, to inform and advice industries on sewerage regulation and waste water prevention and treatment, and to control and enforce the existing environmental laws.

Reforms are required in the Dar es Salaam Sewerage and Sanitation Department (DSSD). To improve the operation and maintenance better guidelines must be written in which tasks, dead lines and responsibilities are clearly described. Furthermore there is a need for better salaries, training, better and more equipment, clear and complete administration of samples and analysis, a clear billing system, and a clear and complete registration of sewerage connections and revenue payments.

Industry must be informed about sewerage regulations, waste water prevention and treatment options. Large industries should manage their own treatment systems. The responsibilities and power to control and enforce environmental laws should be clear defined an executed.

As resources are limited priorities should be made. First the utilization of the present waste water treatment facilities should be optimized. To improve the performance of the waste stabilization ponds a detailed investigation should indicate the most appropriate way to rehabilitate these ponds. But as most waste water is discharged untreated an increase in waste water treatment facilities is needed. Sewerage systems coupled with waste stabilization ponds can be appropriate treatment for densely populated area's with a lot of industries. However the land area needed for the pond might be a problem. For households in less densely populated area's on-site treatment might be more appropriate as this kind of treatment is less expensive.

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Appendix 1: Water Stabilization Pond (WSP) technology

In its simplest form WSP is a basin dug in the ground in which waste water is treated with natural self-purification. In general three types of WSP can be distinguished:

1 Aerobic WSP

Algae and aerobic bacteria are used in the WSP. Algae produce oxygen under influence of light. The bacteria need the oxygen to convert organic matter to carbon dioxide, nitrate (NO_3^-) and phosphate (PO_4^{3-}). This type of WSP is limited in depth because the algae need light. Aeration by surface aerators can improve the results of the treatment.

Aerobic WSP are able to treat weak industrial waste water with negligible amounts of toxic components and non-biodegradable matter. Functions are reduction of biological oxygen demand (BOD) and suspended solids.

The cost of this treatment is minimal. However a large area of land is needed. Disadvantages are: odour, waste water seeping in ground water, effluent contains suspended solids and algae, the algae consume oxygen during night which may cause harm to the aerobic bacteria.

2 Anaerobic WSP

The organic matter in the WSP is degraded by anaerobic bacteria into gases such as methane, hydrogen sulphide, ammonia, and carbon dioxide. Solids settle down into a sludge layer at the bottom of the pond and have to be removed periodically. Once greases form an impervious layer complete anaerobic conditions develop. The disadvantage of anaerobic treatment is the need for another treatment step afterwards. This is necessary as incomplete mineralization of organic compounds occurs resulting in an effluent with a high oxygen demand.

Anaerobic WSP are effective as roughing units prior to aerobic treatment of high strength organic waste water. The BOD removal is relative low (70-85%). This type of WSP needs a smaller land area than aerobic WSP, because it is deeper. Biological degradable industrial waste water can be treated. This WSP should at least be 500 m away from dwelling.

3 Facultative WSP

This is the most commonly used WSP in which aerobic and anaerobic treatment take place simultaneously. Non-settleable matter is stabilisized aerobically in upper layers, where oxygen inputs take place both by algae and atmosphere. Suspended matter is deposited on the bottom and is subjected to anaerobic digestion.

For efficient wastewater treatment several ponds will be placed in series, some pond designed for BOD removal others for disinfection. It is also possible to use fish-ponds or hyacinth-ponds to reduce or suppress algal growth. A simple WSP-system can be described by a simple model (figure 2).

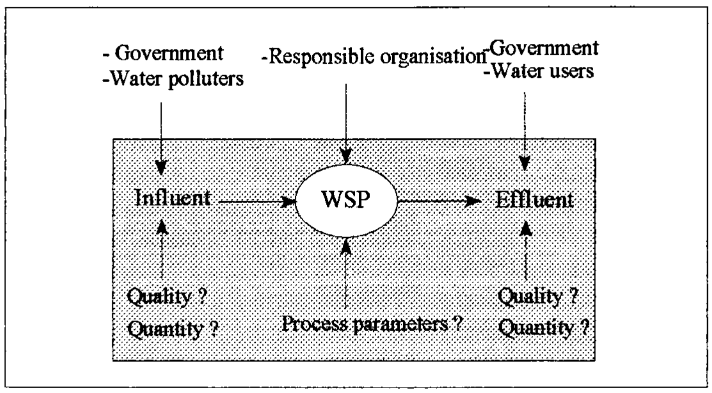

Figure 1: A simple WSP-system and the actors.

Influent:

Quality and quantity requirements must be set to achieve an optimal waste water treatment. Toxic compounds should be avoided in the influent, these will affect the waste water treatment either by killing the micro-organisms or by passing through the WSP and toxicating the effluent. Mineral oil, petroleum products, phenols, pesticides, polychlorinated biphenyls and surfactant are examples of such compounds. Other toxic compounds are salts and compounds containing trace elements like: arsenic, cadmium, copper, chromium, cyanide, lead, mercury, nickel, and zinc.

WSP system:

In a WSP biodegradable organics will partly be eliminated. Effluent qualities are typically 25-50 g/m^3 BOD for aerobic and facultative ponds, and about 50-100 g/m^3 for anaerobic ponds. The BOD loading can be the limiting design factor for WSP. Organic priority pollutants that are resistant to biological decomposition require special attention. Volatilization, adsorption, and then biodegradation are the principle methods for removing trace organics in natural treatment systems.

Removal of pathogens in WSP is due to natural die-off, predation, sedimentation, and adsorption. There is little risk of parasitic infection from pond effluent or from using the effluent in agriculture. There may be some risk when sludge is removed for disposal.

A large percentage of metals present in wastewater will accumulate in the sludge produced during wastewater treatment. As a result metals are often the controlling design parameter for land application of sludge. Metals are not usually the critical design parameter for wastewater treatment systems or water-reuse, with exception of certain industries.

There is a dual concern with respect to nutrients, since their control is necessary to avoid adverse health or environmental effects, but the same nutrients are essential for the performance of the WSP. The nutrients of major importance for both purposes are nitrogen, phosphorus, and potassium. Nitrogen is the controlling parameter for design of many land treatment and sludge application systems.

Effluent:

The requirements that the quality of the effluent must meet depend on its destination. The effluent might be discharged on surface water, be used for irrigation. Not all of the water that enters the WSP will leave as the effluent as some water will penetrate into the ground or evaporate.

Sludge treatment / disposal

All kinds of WSP are slowly filled up with sediments, which must be removed at 1-10 years intervals depending on pond loading, waste water characteristics and pond operation. Natural processes to prepare sludge for final disposal or reuse are composting and reed-bed concepts. Composting provides further stabilization of the sludge and a significant reduction of pathogen content as well as reduction of the moisture content. A major benefit of reed-bed approach is the possibility for multiple-year sludge application and drying before removal is required. Land application of sludge is designed to utilize the nutrient content in the sludge in agricultural, forest, and reclamation projects. Typically, the unit sludge loading is designed on the basis of the nutrients requirements for the vegetation of concern. The metal content of the sludge may then limit both the unit loading and the design application period for a particular site.

Possible processes for sludge treatment are: stabilization, concentration, conditioning, dehydration, vitrification, and wet oxidation.

Environmental impacts of a waste stabilization pond system

The environmental impacts of a WSP are the emissions to air, surface water, ground water and soil, and the solid waste produced by the WSP. The gasses emitted smell and contribute to photo-chemical air pollution (smog) and global warming. As result it may be inconvenient to live close to the WSP. The pollution of ground water, soil and surface water may influence the drink water quality. The sludge produced by the WSP must be disposed in an environmentally, socially and economically sound way. Furthermore, the space occupied by the WSP in a city like Dar es Salaam may cause social or economic problems.

Appendix 2: Connected Industries

1983 - connections according to map availible at DSSD and Howard and Humpreys
1988 - investigated by DSD (Ministry of Water, Energy and Minerals 1988)
1990 - mentioned in report of student (Mgeyekwa, 1990)
1993 - mentioned in artice (Proceedings 1993)
1995 - companies of the investigation paying revenue to DSSD
1995- asked all companies along the sewer to fill the questionaire
Yes - named to be connected
Yes - most probably connected - plot has sewer connection
Yes - are registrated as connected by DSSD

Name:	Desription:	Sewerage cooneection: 1983 Map	1988	1990	1993	1995 DSSD	1995 Question.
1 Achelis	Import of medicals	*Yes*	*Yes*				Yes
2 Afina	?		No				Not located ?
3 Africarriers	Cars	*Yes*	*Yes*				Storm
4 Aluminium Afrca	Metal products	No		Yes	Yes		No
5 Bakhresa	Bread	No	No				No
6 Bandag	Retread Tyres	*Yes*	*Yes*				Yes
7 Bata	Import of shoes	*Yes*	*Yes*				Domstic ?
8 BCC	Constuctors	*Yes*	*Yes*				Closed
9 Beshco	Retailshop	*Yes*	*Yes*				Closed
10 BIMA Motors	Cars	*Yes*	Yes*				Yes
11 Blue Bird	Bus body builders	*Yes*	No				Closed
12 Calico Textile	Cotton fabric	*Yes*	*Yes*	Yes		Yes	Yes
13 Casements Africa	Collapsible gates	Yes	*Yes*	Yes		Yes	Yes
14 Chandaria	Plastic bottles			Yes			Not located ?
15 Cheka Trading	Trade		No				Not located ?
16 Coastal Oil	Edible oil	*Yes*	*Yes*			Yes	Yes
17 Colt Motors	Cars			Yes			Not located ?
18 Combined entrepr.	Water storage tanks	No	No				No
19 Dar Ocean Prod.	Seafood	No	No				Closed
20 Deawoo	Cars	*Yes*	*Yes*				Septic tank
21 Diamond Motors	Cars	*Yes*	Storm				?
22 DT Dobie	Cars	*Yes*	*Yes*	Yes		Yes	Yes
23 Galaxy Paints**	Paints	*Yes*	No	Yes			Yes
24 General Tyre	Selling tyres	*Yes*	*Yes*	Yes			Yes
25 Hamed Ali	Cars	*Yes*	*Yes*				Septic tank ?
26 Incar Tanzania	Cars	Yes	Yes				Yes
27 Infotech / Netlab	Offices	*Yes*	*Yes*				Domestic ?
28 Jandu	Hammermills	No	No				No
29 JeJe	Importing steel	No	No				No
30 Juhudi	Trading	*Yes*	*Yes*				Domestic ?
31 Ladwa	Plastic shoes	*Yes*	Storm				No
32 Light Source	Bulbs and Tubes	*Yes*	*Yes*				Closed
33 Metal Products	Steel drums	Yes	*Yes*				Yes
34 Ministry of Com.	Storage	*Yes*	No				No
35 Nakak	Bus body builders	No					?
36 National distiller.	Spirits	No		Yes			No
37 New P.Put Co	Road constructors	*Yes*	*Yes*				Domestic?
38 Paper Products	Cartons	*Yes*	Storm	Yes		Yes	Yes
39 Pattex Knitwear	Knitted Outerwear	*Yes*	*Yes*			Yes	Yes
40 Sadolin Paints	Paints	*Yes*	*Yes*	Yes		Yes	Yes

* Waste water flows through septic tank to sewer. ** Former Leyland Paints.

Name:	Description:	Sewerage connection: 1983 Map	1988	1990	1993	1995 DSSD	1995 Question.
41 Scania	Trucks	*Yes*	*Yes*			Yes	Yes
42 Shellys	Pharmaceutics	No	No				No
43 Showmax	Aluminium windows	*Yes*	*Yes*				Yes
44 SIDO BM	Metal workshop	*Yes*	No				Yes
45 SIDO Endela	Metal workshop	*Yes*	No				Yes
46 SIDO Foundry	Foundry	*Yes*	No				Yes
47 SIDO Garage	Cars	*Yes*	No				Yes
48 SIDO Tanz.Galv.	Electroplating	*Yes*	No				Yes
49 SIDO Meida	Electroplating	*Yes*	No				Yes
50 SIDO Mwanlogo	Metal Workshop	*Yes*	No				Yes
51 SIDO Tanz. Spare	Metal Workshop	*Yes*	No				Yes
52 SIDO Tanz.Cycle	Electroplating	*Yes*	No				Yes
53 SIDO Tricycle	Metal Workshop	*Yes*	No				Yes
54 SIDO Paper	Office requisite	*Yes*	No				Yes
55 SIDO Tailoring	School	*Yes*	No				Yes
56 SIDO Woodprod.	Furniture	*Yes*	No				Yes
57 SIDO Worshop	Metal workshop	*Yes*	No				Yes
58 SIDO Worshop	Metal workshop	*Yes*	No				Yes
59 SIDO Worshop	Metal workshop	*Yes*	No				Yes
60 SIDO Worshop	Metal workshop	*Yes*	No				Yes
61 SIDO YMCA	Electroplating	*Yes*	No				Yes
62 Soxy	Socks	*Yes*					Closed
63 Star Garage	Cars	*Yes*	Yes				Yes
64 Steel Wool Tanz.	Steel wool		Storm	Yes			Not located ?
65 Suchak plastic	Plastic objects	*Yes*	*Yes*				Not started
66 Tanita	Cashewnut	*Yes*		Yes			Closed
67 Tanz. Aggregates			No			Yes	Not located ?
68 Tanz. Autoparts	Autoparts	*Yes*	*Yes*	Yes			Yes*
69 Tasia	Carsprings	*Yes*	Storm	Yes		Yes	Yes
70 Tazara Housing	Residential	Yes				Yes	Yes
71 Tazara Station	Railway	Yes		Yes			Yes
72 Tazara Workshop	Metal workshop	*Yes*		Yes	Yes	Yes	Yes
73 Tropical Foods	Jams& Squashes	*Yes*	Storm	Yes			Yes
74 Wade Adams			No			Other side of the road ?	
75 Yakub	Cars	*Yes*	*Yes*				*Yes*
76 Yuasa Battery	Dry Batteries	*Yes*	*Yes*	Yes	Yes	Yes	Yes
77 Zahra Bottlers	Softdrink	*Yes*	*Yes*			Yes	Yes
	Totals:	46	30	19	3	12	37

* Through septic tank.

1988 Investigation by Ministry of Water, Energy and Minerals

Industries connected to the storm sewers in 1988, may be reconnected to the foul sewer by now. The rest of the industries in between manhole F/P-06 and F/P-34 were connected to the sewer in 1988. This is the part of Pugu road from Calico till the end of the sewer at that time. There were plans of extending the sewer 500 m so that Al Arby Bus Service, Combined Enterprises Ltd, Shellys Ltd, C.C.M. Compound and a unplanned residential area could get a sewer-connection.

1990 Student Public Health Engineering at Ardhi Institute of Dar es Salaam (Mgeyekwa)

In this report about the performance of Vingunguti WSP 18 industries are said to be connected to the WSP.

1994 National Workshop on WSP (Chaggu in Proceedings 1994)

Yuasa Battery, Tazara Workshop and Aluminium Africa are said to discharge on the Vingunguti WSP. However on the map of the "Rehabilitation of Tazara / Pugu road / Buguruni foul sewerage, Januari 1983 " there is no possible sewerage connection to Aluminium Africa. The waste water of Aluminium Afrrica flows untreated to the Indian Ocean.

Appendix 3: Questionnaire.

23 May 1995

TO WHOM IT MAY CONCERN

Dear Sir / Madame,

As part of cleaner production initiatives in Vingunguti areas industries are selected for investigation of wastewater management programme's four key elements - water conservation, wastewater treatment, recycling of treated wastewater and land disposal of any surplus treated wastewater.

For this purpose data collection will be carried out by Annelise Balklame from Endihoven University, the Netherlands. I am therefore requesting you for your assistance in this matter.

Enclosed please find a copy of a questionnaire to be filled by your company.

Thanking you in advance for your kind cooperation.

Yours sincerely,

Michael Yhdego

Cleaner Production Consultant

Rapid assesment of industrial waste water, Vingunguti area.

The objective of this questionnaire is to obtain data needed to improve waste water collection and treatment. Please fill in this questionnaire as detailed as possible. If the space given for answers is not enough please use the back site of the paper. If the statement behind ☐ is correct please fill the box (☒). Dots (...) are set in places where you are meant to give a specification. Thank you for your cooperation.

1. General information

Company name:	ZAHRA BOTTLERS LTD
Address:	PO BOX 1912, D'SALAAM
Owner of company:	☒ private owned by : M. VIRAN ☐ parastatel owned by:..................................... ☐ governmental
Telephone: Telefax: Telex:	864344 862896
Contact person: Position:	L.J NDABILA CHEMIST
Date:	11.7.95

2. General production information

Product:	SOFT DRINKS
Production capacity	100 CRATES/HOUR
Working hours:	12 HRS/DAY
Number of employees:	60
Number of engineers:	2

3. Production information:

	1992	1993	1994	1995 (projected)
Total production quantity	65884	178,840	171081	250,000
Total production cost (TSh)	61.6 million	117.3 m	136 m	175 m
Electricity use (MWh)				

	1992	1993	1994	1995 (projected)
Electricity cost (TSh)				
Water use (m^3)			ESTIMATE	1533.4 m^3/MONTH
Water cost (TSh) (NUWA)			FIXED	33350 TSH /MONTH
Wast water cost (Tsh) (OSSD)				NO CHARGE

4. Proces scheme:

1. - CLEANING OF SAND & CARBON FILTERS (BACKWASHING)
2. - CLEANING OF SYRUPROOM, BOTTLING HALL, AND ALL MACHINES (C.I.P)
3. - CLEANING AND RINSING OF BOTTLES IN BOTTLEWASHER.
4. - MIXING OF SYRUP AND WATER BY PROPORTIONING PUMP.
5. - BOTTLING OF THE PRODUCT
6. - PACKING OF THE PRODUCT

5. Materials:

Raw materials:	Quantity (kg/day) :
1) SUGAR	1040.0
2) CITRIC ACID	15.0
3) CONCETRATES	
4) PRESERVATIVE	
5) WATER	1000.00 (1M³)
6)	
7)	
By products:	**Quantity (kg/day) :**
1)	
2)	
Products:	**Quantity (kg/day) :**
1) SCHWEPPES	300 CRATES
2) CANADA DRY	300 CRATES
3) CRUSH	300 CRATES
4) VIMTO	300 CRATES

6. Water usage:

Source:	Water used for:	(m^3/day)
1) Piped water from National Urban Water Authority (NUWA)	☒ processing ☐ cooling ☐ washing ☐ domestic ☐ other	5·8 .. 50 .. .. total: 55·8
2) Ground water	☐ processing ☐ cooling ☐ washing ☐ domestic ☐ other	.. .. total: ..
3) Surface water	☐ processing ☐ cooling ☐ washing ☐ domestic ☐ other	.. .. total: ..
4) Other water sources:	☐ processing ☐ cooling ☐ washing ☐ domestic ☐ other	.. .. total: ..

7. Waste water production:

Produced in process step:	m^3/day	Waste water produced contains:
1) BOCKWASHING FILTERS	3·0 (6%)	FREE CHLORINE CALCIUM HYDROXIDE
2) CLEANING SURYP ROOM.	1·00 (2%	RESIDUE OF SOFT DRINKS
3) BOTTLEWASHER	50.0 (92%	SODIUM HYDROXIDE
4)		
Total:	54·0 (100%)	

8. Waste water control:

Characteristic of waste water:	Measurement:	Value:
Quantity	none / daily / weekly /	m^3/day
Temperature	none / daily / weekly /	°C
pH	none / daily / weekly /	
Suspended solids	none / daily / weekly /	mg/l
Total solids	none / daily / weekly /	mg/l
BOD_5^{20}	none / daily / weekly /	mg/l
COD	none / daily / weekly /	mg/l
Colour	none / daily / weekly /	
Others:	none / daily / weekly /	

9. Waste water treatment:

Method of treatment:	
Method of discharging:	□ through septic tank ☒ through open channel □ through pipeline (sewer) □ other:.............
Final destination waste water:	□ soakaway pit ☒ domestic sewer to Waste Sabilisation Pond □ domestic sewer directly to Indian Ocean □ stormwater sewer □ river □ other:.............
Possibilities for water reuse/recycling:	

Thank you for cooperating.

Appendix 4: Waste water terminology.

BOD_5 - biological oxygen demand

The biological oxygen demand is an approximate measure of the amount of biochemically degradable organic matter present in a water sample. It is defined by thge amount of oxygen required for the aerobic micro organisms present in the sample to oxidise the organic matter to a stable inorganic form. The method is subject to various complicating factors such as the oxygen demand resulting from respiration of algae in the sample and possible oxidation of ammonia by nitrifying bacteria if present. The presence of toxic substances in a sample affects microbial activity leading to a reduction in the measured BOD. As the conditions in a BOD bottle differ from those in surface water the measured BOD should be interpretated carefully.

BOD is usually measured by standardised laboratory procedures which measure the amount of oxygen consumed aftre incubating the sample in the dark at a specified temperature, usually 20 °C, for a specific period of time, usually five days. This gives rise to the common used terms BOD_5 and BOD_5^{20}.

BOD measurements are usually lower than COD measurements. Unpolluted waters typically have BOD values of 2 mg O_2/l or less, whereas those receiving waste water may have values up to 10 mg O_2/l or more. Raw sewerage has a BOD of about 600 mg O_2 /l, whereas treated sewrage effluents have BOD values ranging from 20 to 100 mg O_2/l. Industrial wastes may have BOD values up to 25,000 mg O_2/l (Chapman 1992, p80).

CN^- - cyanide

Compounds of cyanide enter fresh waters with industrial waste waters such as those from the electroplating industry. Cyanides occur in waters in ionic form or as weakly dissociated hydrocyanic acid or complex compounds with metals. The toxicity of cyanides depends on their speciation; some ionic forms and hydrodyanic acid are highly toxic. The toxicity of complex compounds of cyanide depend on their stability.

The World Health Organization recommends a maximum concentration of 0.1 mg cyanide per litre drinking water. Many countries apply stricter standards for drinking water and natural waters of importance to fishing. Cyanide is listed on the black list and as such discharge should be prevented with the best technology availible.

Ionic cyanide concentration in water is reduced by carbonic and other acids transforming the ionic form into the volatile hydrocyanic acid. However the rpincipe mechenism of decreasing levels in oxidation, including biochemical oxidation, followed by hydrolysis. Strong sunlight and warm seasons favour biochemical oxidation causing reduction of cyanide concentration. Cyanides, especially ionic forms, are easily adsorbed by suspened matter and bottom sediments.

COD - chemical oxygen demand

The chemical oxygen demand is a measure of the oxygen equivalent of organic matter in a water sample that is suceptible to oxydation by a strong chemical oxidant, such as dichromate. The COD test is non-specific , as it does not identify the oxidisable material or differentiate between organic and inorganic material present. Similary it does not indicate the total organic carbon present, as some organic compounds are not oxidised by the dichromate method whereas some inorganic compounds are oxidised. Nevertheless, COD is a useful, rapidly measured, variable for many industrial wastes and has been in use for several decades.

The concentrations of COD observed in surface waters range from 20 mg oxygen per litre water in unpolluted water to greater than 200 mg O_2/l in water receiving effluents. Industrial waste waters may have COD levels from 100 to 60,000 mg O_2/l (Chapman 1992, p79).

Cr^{6+} and Cr_{total} - chromium

The ability of a water body to support aquatic life, as well as its suitability for other uses depends on many trace elements. Some metals present in trace concentrations are important for physiological functions of living tissue and regulate many biochemical processes. The same metals, however, dicharged by domestic sewers and industries cause elevated concentrations which can have severe toxicological effects on the aquatic ecosystem.

Metals in natural waters can exist in truly dissolved, colloidal and suspended forms. The toxidity of metals in water depends on the degree of oxidation together with the form in which the metal occurs. As a rule, the ionic form of a metal is the most toxic form.

Chromium is used to make metal objects corrosion resistance. It is present in effluents of electroplating industries. The most toxic form Cr^{6+}, is a priority pollutant present on the black list. As it is carciogenic and corrosive on tissue. Discharge of black list compound should be prevented by using the best available technology. Other chromium forms are on the grey list which means that discharge should be prevented by using the most appropriate technology.

Cu - copper (see also chromium)

Copper is discharged by metal insdustries, for instance when using the metal for electroplating. Copper is a priority pollutant placed on the grey list which mean that discharge shold be prevented by using the most appropriate technology.

Faecal coliforms

The most common risk to human health associated with water stems from the presence of disease-causing micro-organisms. Many of these micro-organisms originate from water polluted with human excrement. Human faeces can contain a variety of intsetinal pathogens which cause diseases ranging from mild gastro-enteritis to serious, and possibly fatal, dysentery, cholera and typhoid. Fresh water also contains indigenous micro-organisms, including bacteria, fungi, protozo and algae, a few of ehich are known to produce toxins and transmit, or cause diseases.

To avoid human infection, the World Health Organization recommended concentration for drinking water is zero organisms per 100 ml. Typical municipal raw sewage can contain 10 to 100 million coliform bacteria per 100 ml and 1 to 50 million faecal streptococci per 100 ml. Poor treatment of waste water can lead to pathogen contamination of surface and ground water. Survival of microbiological pathogens depend on the water quality, particular the turbidity, oxygen level, nutrients, and temperature. Micro-organisms often become adsorbed on sand, clay and sediment particles, resulting in accumulation of these organisms in river and lake sediments (Chapman 1992, p101).

TDS - total dissolved solids
TSS - total suspended solids

The term 'solids' is widely used for the majority of compounds which are present in natural water and remain in a solid state after evaporation. Total suspended solids and total dissolved solids correspond to non-fiterable and filterable residue, repectively.

The type and concentration of suspended matter controls the turbidity and transparancy of the water. Suspended matter consists of silt, clay, fine particles, soluble organic compounds, plankton and other micro organisms.

Ni - nickel (see also chromium)

Nickel is used in electroplating. The pollutant is on the grey list meaning that dischareg should be prevented with the most appropriate technology.

N_{total} - nitrogen compounds

Nitrogen is essential for living organisms as an important constituent of proteins. In the environment, inorganic natrogen occurs in a range of oxidation states as nitrate (NO_3^-) and nitrite (NO_2^-), the ammonium ion (NH_4^+) and the molecular nitrogen (N_2). Organic nitrogen consists mainly of protein substances and the product of their biochemical transformation.

As nitrogen is essential to living organisms it must be present in the biological waste water treatment system. However high nitrogen concentrations in the effluent of a waste water treatment system contribute to eutrophication of surface waters.

Foodprocessing effluents are often high in nitrate. Run-off from agriculture using artificial fertilisers also contributes to eutrification.

Nitrogen oxides are priority pollutants. Ammonium and nitrites are grey list pollutants. Discharge should be prevented using the most appropriate technology.

P_{total} - phosphorus compounds (see also nitrogen compounds)

Phosphorus is an essential nutrient for living organisms and exists in water bodies as dissolved and particulate species. It is generally the limiting nutrient for algal growthand, therefore, controls the primary productivity of a water body. Artificial increases due to human activity are the principal cause of eutrophication.

Natural sources of phoshorus are mainly the wheathering of phosphorys bearing rocks and decomposition of organic matter. Domestic waste water, particularly those containing detergents, industrial effluents and fertiliser run-off contribute to elevated levels in surface waters.

Phosphate is a priority pollutant and is listed on the grey list together with phosphorus compounds. Therefore discharge should be prevented with the most appropriate technology.

Oil

Fats and oils are components (esters) of alcohol or glycerol (glycerin) with fatty acids. Fats are among the more stable organic compounds and are not easily decomposed by bacteria. Fats and oils are discharged by households anf industries.

Mineral oil and petroleum products are major pollutants responsible for ecological damage especially in inland surface waters. Oil is distributed in water bodies in different forms; dissolved, film, emulsion and sorbed fractions. Mineral oils sometimes reach the sewers in considerable volumes from shops, garages, and streets.

To an even greater extend than fats, oils, and soaps, the mineral oils tend to coat surfaces. If not removed before discharge of waste water, it can interfere with the biological life, thus causing problems, sewers, trewatment facilities and surface waters. The permissible concentration of mineral oil and petroleum products in water depends on the intended use of the water. Concentrations of more than 0.3 mg crude oil per litre can cause toxic effects in fresh water fish.

Mineral oils are priority pollutants of the black list and their discharge should be prvented with the best technology availible.

Zn - zinc (see also chromium)

Zinc is used by several electroplating industries as investigated in this report. Zinc priority pollutant placed on the grey list. Discharge should be prevented by using the most appopriate technology.

Appendix 5: Model for design calculations.

RAPID ASSESSMENT DATA:

	QUESTIONAIRE DATA:										CALCULATED DATA:					
	Production:			Waste water flow:							Waste water flow:			Waste water BOD:		
	1994 (t/year)	1995 (t/year)	100% cap (t/year)	1994 (m3/year)	1995 (m3/year)	100% (m3/year)		1994	1995	100%	1994 (m3/year)	1995 (m3/year)	100% (m3/year)	1994 (t/year)	1995 (t/year)	100% (t/year)
Food & beverage:																
Coastal Oil	4150	7500	25000	1000	1807	6024					28220	51000	170000	103	187	623
Tropical Foods	221	480	2456	1400	3041	15556					936	2032	10395	2	4	19
Zahra Bottlers	1026	1500	2052	10000	14620	20000					4412	6450	8824	2	3	4
Textile:																
Calico	84	600	840	12000	85680	120000					22260	158936	222600	13	93	130
Pattex Knitwear	3	5	5	3600	6588	6588					567	1038	1038	0	1	1
Paper products:																
Paper Products	22%			5920	5920	26909	Popequiv:	108	108	489	5920	5920	26909	2	2	9
Chemical products:																
Galaxy Paints	39%	41%		1250	1300	3205	Popequiv:	23	24	58	1250	1300	3205	0	0	1
Sadolin Paints	57%	84%		1700	2499	2982	Popequiv:	31	45	54	1700	2499	2982	1	1	1
Metal products:																
Electroplating				6000	6000	6000					6000	6000	6000			
Others				15149	15149	15149	Estprod:	275	275	275	15149	15149	15149	5	5	5
Car maintenace:																
Total				17324	17324	17324	Popequiv:	315	315	315	17324	17324	17324	6	6	6
Domestic:																
Inhabitants				63800	63800	63800	Inhabit:	1160	1160	1160	63800	63800	63800	21	21	21
Employees				17411	17411	17411	Employees:	795	795	795	17411	17411	17411	6	6	6
			TOTAL:	156554	241139	320948				TOTAL:	184948	348859	565637	161	328	825

WSP-DESIGN ACCORDING TO MARA 1992

1. Global design equation:	SL=350*(1107-0002*T)^(T-25)	SL = surafce loading (kg/ha*day) T = mean air temperature in coldest month (C)
2. Pond surface area:	Af=(10*Li*Q)/SL	Af = surface area of facultative pond (m2) Li = influent BOD (mg/l = g/m3) Q = influent flow (m3/day)
3. Retention time:	RT=2*Af*D/(2*Q-0001*Af*e)	RT = retention time (days) D = pond depth (m) e = net evaporation (mm/day)
4. Effluent flow:	Qe=Q-0001*Af*e	Qe = effluent flow (m3/day)
5. Faecal coliform removal:	Ne=N/(1+k*RT) k=26*(119)^(T-20)	Ne = number of faecal cliforms per 100 ml of effluent N = number of faecal coliforms per 100 ml influent k = first order rate constant for faecal coliform removal (1/day)

ASSESSMENT OF WSP-DESIGN Rapid Assessment Case

Flow: according questionnaire
BOD: according to Rapid Assessment

INPUT:

Temperature	°C	23.45	(Ministry of Tourism, 1994)
Net evaporation	(mm/day)	-2	(Times, 1993/94)
Flow from anaerobe	(m3/day)	240	(Mgeyekwa, 1990, refering to Howard & Humphrey)
Depth pond 1	(m)	1.30	(Mgeyekwa, 1990, refering to Howard & Humphrey)
Depth pond 2	(m)	1.15	(Mgeyekwa, 1990, refering to Howard & Humphrey)
Depth pond 3	(m)	1.10	(Mgeyekwa, 1990, refering to Howard & Humphrey)
Depth pond 4	(m)	1.00	(Mgeyekwa, 1990, refering to Howard & Humphrey)
BOD removal pond 1	(%)	49	(Mgeyekwa, 1990, refering to Howard & Humphrey)
BOD removal pond 2	(%)	34	(Mgeyekwa, 1990, refering to Howard & Humphrey)
BOD removal pond 3	(%)	28	(Mgeyekwa, 1990, refering to Howard & Humphrey)
BOD removal pond 4	(%)	10	(Mgeyekwa, 1990, refering to Howard & Humphrey)
1 Order FC removal	(1/days)	5	(Mara, 1992)
Influent flow	(m3/day)	429	
Influent BOD	(g/m3)	1030	

OUTPUT:

1. First facultative pond:		
Surface loading	(kg/(ha*day))	320
Pond surface area	(m2)	13821
Retention time	(days)	41
Effluent flow	(m3/day)	457
2. Second facultative pond:		
Influent BOD	(g/m3)	523
Surface loading	(kg/(ha*day))	320
Pond surface area	(m3)	7463
Retention time	(days)	18
Effluent flow	(m3/day)	711
3. First maturation pond:		
Influent BOD	(g/m3)	344
Surface loading	(kg/(ha*day))	320
Pond surface area	(m3)	7660
Retention time	(days)	12
Effluent flow	(m3/day)	727
4. Second maturation pond:		
Influent BOD	(g/m3)	249
Surface loading	(kg/(ha*day))	320
Pond surface area	(m3)	5657
Retention time	(days)	8
Effluent flow	(m3/day)	738
Effluent BOD	(g/m3)	24
5. Total coliform removal:	(%)	100.00000

NOTE:
Maturation ponds are usually designed on pathogens removal. Since no information about influent pathogens is avalible, the ponds are designed as facultative ponds. According to Reed 1995 normal retention time for BOD removal is sufficient for pathogen removal if the total retention time exceeds 20 days. To indicate the appropriateness of the design of the maturation ponds the faecal coliform removal is calculated afterwards.

ASSESSMENT OF WSP-DESIGN: Rapid Assessment case

Flow: according Rapid Assessment
BOD: according to Rapid Assessment

INPUT:

Temperature	(C)	23.45
Net evaporation	(mm/day)	-2
Flow from anaerobe	(m3/day)	240
Depth pond 1	(m)	1.30
Depth pond 2	(m)	1.15
Depth pond 3	(m)	1.10
Depth pond 4	(m)	1.00
BOD removal pond 1	(%)	49
BOD removal pond 2	(%)	34
BOD removal pond 3	(%)	28
BOD removal pond 4	(%)	10
1 Order FC removal	(1/days)	5
Influent flow	(m3/day)	507
Influent BOD	(g/m3)	872

OUTPUT:

1. First facultative pond:

Surface loading	(kg/(ha*day)	320
Pond surface area	(m2)	13821
Retention time	(days)	35
Effluent flow	(m3/day)	534

2. Second facultative pond:

Influent BOD	(g/m3)	442
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	7394
Retention time	(days)	16
Effluent flow	(m3/day)	789

3. First maturation pond:

Influent BOD	(g/m3)	291
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	7191
Retention time	(days)	10
Effluent flow	(m3/day)	804

4. Second maturation pond:

Influent BOD	(g/m3)	211
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	5294
Retention time	(days)	7
Effluent flow	(m3/day)	814
Effluent BOD	(g/m3)	20

5. Total coliform removal: (%) 99.99999

ASSESSMENT OF WSP-DESIGN: Rapid Assessment case

Flow: according questionnaire
BOD: according to Rapid Assessment

INPUT:

Temperature	(C)	23.45
Net evaporation	(mm/day)	-2
Flow from anaerobe	(m3/day)	240
Depth pond 1	(m)	1.30
Depth pond 2	(m)	1.15
Depth pond 3	(m)	1.10
Depth pond 4	(m)	1.00
BOD removal pond 1	(%)	49
BOD removal pond 2	(%)	34
BOD removal pond 3	(%)	28
BOD removal pond 4	(%)	10
1 Order FC removal	(1/days)	5
Influent flow	(m3/day)	429
Influent BOD	(g/m3)	1030

OUTPUT:

1. First facultative pond:

Surface loading	(kg/(ha*day)	320
Pond surface area	(m2)	13821
Retention time	(days)	41
Effluent flow	(m3/day)	457

2. Second facultative pond:

Influent BOD	(g/m3)	523
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	7463
Retention time	(days)	18
Effluent flow	(m3/day)	711

3. First maturation pond:

Influent BOD	(g/m3)	344
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	7660
Retention time	(days)	12
Effluent flow	(m3/day)	727

4. Second maturation pond:

Influent BOD	(g/m3)	249
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	5657
Retention time	(days)	8
Effluent flow	(m3/day)	738
Effluent BOD	(g/m3)	24

5. Total coliform removal: (%) 100.00000

ASSESSMENT OF WSP-DESIGN: Adjusted BOD Case

Flow: according questionnaire
BOD: industry adjusted

INPUT:

Temperature	(C)	23.45
Net evaporation	(mm/day)	-2
Flow from anaerobe	(m3/day)	240
Depth pond 1	(m)	1.30
Depth pond 2	(m)	1.15
Depth pond 3	(m)	1.10
Depth pond 4	(m)	1.00
BOD removal pond 1	(%)	49
BOD removal pond 2	(%)	34
BOD removal pond 3	(%)	28
BOD removal pond 4	(%)	10
1 Order FC removal	(1/days)	5
Influent flow	(m3/day)	429
Influent BOD	(g/m3)	390

OUTPUT:

1. First facultative pond:

Surface loading	(kg/(ha*day)	320
Pond surface area	(m2)	5227
Retention time	(days)	16
Effluent flow	(m3/day)	439

2. Second facultative pond:

Influent BOD	(g/m3)	198
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	2716
Retention time	(days)	7
Effluent flow	(m3/day)	685

3. First maturation pond:

Influent BOD	(g/m3)	130
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	2788
Retention time	(days)	4
Effluent flow	(m3/day)	690

4. Second maturation pond:

Influent BOD	(g/m3)	94
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	2032
Retention time	(days)	3
Effluent flow	(m3/day)	694
Effluent BOD	(g/m3)	9

5. Total coliform removal: (%) 99.99988

ASSESSMENT OF WSP-DESIGN: Adjusted BOD Case

Flow: according questionnaire
BOD: industry & domestic adjusted

INPUT:

Temperature	(C)	23.45
Net evaporation	(mm/day)	-2
Flow from anaerobe	(m3/day)	240
Depth pond 1	(m)	1.30
Depth pond 2	(m)	1.15
Depth pond 3	(m)	1.10
Depth pond 4	(m)	1.00
BOD removal pond 1	(%)	49
BOD removal pond 2	(%)	34
BOD removal pond 3	(%)	28
BOD removal pond 4	(%)	10
1 Order FC removal	(1/days)	5
Influent flow	(m3/day)	429
Influent BOD	(g/m3)	363

OUTPUT:

1. First facultative pond:

Surface loading	(kg/(ha*day)	320
Pond surface area	(m2)	4870
Retention time	(days)	15
Effluent flow	(m3/day)	439

2. Second facultative pond:

Influent BOD	(g/m3)	184
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	2527
Retention time	(days)	7
Effluent flow	(m3/day)	684

3. First maturation pond:

Influent BOD	(g/m3)	121
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	2594
Retention time	(days)	4
Effluent flow	(m3/day)	689

4. Second maturation pond:

Influent BOD	(g/m3)	88
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	1889
Retention time	(days)	3
Effluent flow	(m3/day)	693
Effluent BOD	(g/m3)	8

5. Total coliform removal: (%) 99.99985

ASSESSMENT OF WSP-DESIGN: Increased Prod.case 1995

Flow: according questionnaire
BOD: according to Rapid Assessment

INPUT:

Temperature	(C)	23.45
Net evaporation	(mm/day)	-2
Flow from anaerobe	(m3/day)	240
Depth pond 1	(m)	1.30
Depth pond 2	(m)	1.15
Depth pond 3	(m)	1.10
Depth pond 4	(m)	1.00
BOD removal pond 1	(%)	49
BOD removal pond 2	(%)	34
BOD removal pond 3	(%)	28
BOD removal pond 4	(%)	10
1 Order FC removal	(1/days)	5
Influent flow	(m3/day)	661
Influent BOD	(g/m3)	1362

OUTPUT:

1. First facultative pond:

Surface loading	(kg/(ha*day)	320
Pond surface area	(m2)	28139
Retention time	(days)	53
Effluent flow	(m3/day)	717

2. Second facultative pond:

Influent BOD	(g/m3)	691
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	15491
Retention time	(days)	24
Effluent flow	(m3/day)	988

3. First maturation pond:

Influent BOD	(g/m3)	455
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	14058
Retention time	(days)	15
Effluent flow	(m3/day)	1016

4. Second maturation pond:

Influent BOD	(g/m3)	329
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	10453
Retention time	(days)	10
Effluent flow	(m3/day)	1037
Effluent BOD	(g/m3)	31

5. Total coliform removal: (%) 100.00000

ASSESSMENT OF WSP-DESIGN: Increased Prod.case 100%

Flow: according questionnaire
BOD: according to Rapid Assessment

INPUT:

Temperature	(C)	23.45
Net evaporation	(mm/day)	-2
Flow from anaerobe	(m3/day)	240
Depth pond 1	(m)	1.30
Depth pond 2	(m)	1.15
Depth pond 3	(m)	1.10
Depth pond 4	(m)	1.00
BOD removal pond 1	(%)	49
BOD removal pond 2	(%)	34
BOD removal pond 3	(%)	28
BOD removal pond 4	(%)	10
1 Order FC removal	(1/days)	5
Influent flow	(m3/day)	879
Influent BOD	(g/m3)	2572

OUTPUT:

1. First facultative pond:		
Surface loading	(kg/(ha*day)	320
Pond surface area	(m2)	70737
Retention time	(days)	97
Effluent flow	(m3/day)	1021
2. Second facultative pond:		
Influent BOD	(g/m3)	1305
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	41658
Retention time	(days)	45
Effluent flow	(m3/day)	1344
3. First maturation pond:		
Influent BOD	(g/m3)	859
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	36125
Retention time	(days)	29
Effluent flow	(m3/day)	1416
4. Second maturation pond:		
Influent BOD	(g/m3)	621
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	27522
Retention time	(days)	19
Effluent flow	(m3/day)	1471
Effluent BOD	(g/m3)	59
5. Total coliform removal:	(%)	100.00000

ASSESSMENT OF WSP-DESIGN: Actual Design

Flow: according to Howard & Humphrey
BOD: design population 12,500 people

INPUT:

Temperature	(C)	23.45
Net evaporation	(mm/day)	-2
Flow from anaerobe	(m3/day)	240
Depth pond 1	(m)	1.30
Depth pond 2	(m)	1.15
Depth pond 3	(m)	1.10
Depth pond 4	(m)	1.00
BOD removal pond 1	(%)	49
BOD removal pond 2	(%)	34
BOD removal pond 3	(%)	28
BOD removal pond 4	(%)	10
1 Order FC removal	(1/days)	5
Influent flow	(m3/day)	1762
Influent BOD	(g/m3)	284

OUTPUT:

1. First facultative pond:		
Surface loading	(kg/(ha*day)	320
Pond surface area	(m2)	15651
Retention time	(days)	11
Effluent flow	(m3/day)	1793
2. Second facultative pond:		
Influent BOD	(g/m3)	144
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	8081
Retention time	(days)	5
Effluent flow	(m3/day)	2049
3. First maturation pond:		
Influent BOD	(g/m3)	95
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	6082
Retention time	(days)	3
Effluent flow	(m3/day)	2062
4. Second maturation pond:		
Influent BOD	(g/m3)	69
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	4423
Retention time	(days)	2
Effluent flow	(m3/day)	2070
Effluent BOD	(g/m3)	7
5. Total coliform removal:	(%)	99.99961

ASSESSMENT OF WSP-DESIGN: Actual adjusted surfaces

Flow: according to Howard & Humphrey
BOD: design population 12,500 people

INPUT:

Temperature	(C)	23.45
Net evaporation	(mm/day)	-2
Flow from anaerobe	(m3/day)	240
Depth pond 1	(m)	1.30
Depth pond 2	(m)	1.15
Depth pond 3	(m)	1.10
Depth pond 4	(m)	1.00
BOD removal pond 1	(%)	49
BOD removal pond 2	(%)	34
BOD removal pond 3	(%)	28
BOD removal pond 4	(%)	10
1 Order FC removal	(1/days)	5
Influent flow	(m3/day)	1762
Influent BOD	(g/m3)	284

OUTPUT:

1. First facultative pond:		
Surface loading	(kg/(ha*day)	320
Pond surface area	(m2)	9600
Retention time	(days)	7
Effluent flow	(m3/day)	1781
2. Second facultative pond:		
Influent BOD	(g/m3)	144
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	11600
Retention time	(days)	7
Effluent flow	(m3/day)	2044
3. First maturation pond:		
Influent BOD	(g/m3)	95
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	13776
Retention time	(days)	7
Effluent flow	(m3/day)	2072
4. Second maturation pond:		
Influent BOD	(g/m3)	69
Surface loading	(kg/(ha*day)	320
Pond surface area	(m3)	14175
Retention time	(days)	7
Effluent flow	(m3/day)	2100
Effluent BOD	(g/m3)	7
5. Total coliform removal:	(%)	99.99993

Appendix 6: Summary of analysis at Vingunguti-WSP.

Table 1: WSP Influent.

Analysis:		**DSSD 1987**	**MWEM# 1988**	**Mgeyekwa 1990**	**DSSD 1992**	**DSSD 1993**
Biological:						
BOD_5	(mg/l)	112-265	165*	198.4-322.4	120	
Facultative pond load	(kg/ha.day)		230	205.2		
Fac.pond load mean peak	(kg/ha.day)			261.3		
Facultative pond load	(g/m^3.day)			15.8		
Fac.pond load mean peak	(g/m^3.day)			20.1		
Feacal Coliforms	(FC/100ml)			$(4.1\text{-}73.4)10^5$		
Organic loading	(kg/day)		248			
Chemical:						
Cadmiun	(mg/l)			0-0.1		
Chloride	(mg/l)				2.8	11.3
COD	(mg/l)	205-420	168**		6	7.0
Copper	(mg/l)		0.2			
NH_3-N	(mg/l)	0.5-4.68		6.8		
Nickel	(mg/l)		trace			
Lead	(mg/l)		0.3-5.2	0.4-1.6		
PV	(mg $KMnO_4$/l)			460.8-658		
Zinc	(mg/l)		0.1-0.4	0.1-0.2		
Physical:						
Dissolved oxygen	(mg/l)		4.1-17.7	2.29-3.15	3.6	
Flow piped sewer	(m^3/day)		1065-1500	756.62		
Flow mean peak hourly	(m^3/day)			963.52		
Flow pond 2 to 3	(m^3/day)			117.73		
Flow m.p.hourly 2 to 3	(m^3/day)			288.15		
pH			7.1-10.6	7.1-8.1		
Redoxpotential	(mV)		40-254			
Suspended solids	(mg/l)	0.1-750		607-1052	148	51
Temperature	(°C)		27.1-30.8	28.8-30.8		

Minstry of Water, Energy and Minerals * Average ** Single composite sample

Table 2:Vingunguti WSP effluent.

Analysis		**DSSD 1987**	**Haskoning 1988**	**Mgeyekwa 1990**	**DSSD 1992**	**DSSD 1993**	**DSSD 1994**
Biological:							
BOD_5	(mg/l)	52-70	3-19	41.7-72.1	4-100	6-90	35-45
Fecal Coliform	(FC/100ml)		200-700	35-201			
T Coliforms	(TC/100ml)		0-200				
Chemical:							
Cadmium	(mg/l)			not detectable			
COD	(mg/l)	92-314	65-146		20.0	24.2	
Chloride	(mg/l)				5.7	15.6	
Kj-N	(mg/l)		7.3-17.4				
Lead	(mg/l)			trace			
NH_3-N	(mg/l)	0-4.10	0-0.417	0.66-1.14			
P total	(mg/l)		0.166-0.360				
PO_4-P	(mg/l)		0.02-0.066				
PV	(mg KMO_4/l)			187-272			
Zinc	(mg/l)			trace			
Physical:							
Dissolved oxgygen	(mg/l)		9.0-9.5	9.59-13.85		4.4	
pH				9.17-9.99			
Suspended solids	(mg/l)	0.1-520	50-1010	140.5-444.9		104	126
Temperature	(°C)		27.3-29.2	28.5-30.5			

FIRST SCHEDULE

Temporary Standards for receiving Waters

Category 1: Water suitable for drinking water supplies, swimming pools, food and beverage manufacturing industries, pharmaceuticals manufacturing—industries or industries requiring a water source of similar quality.

Category 2: Water suitable for use in feeding domestic animals; in fisheries, shell cultures, recreation and water contact sports.

Category 3: Water suitable for irrigation and other industrial activities requiring water of standards lower than those of water in category 1 or 2.

Substance	Characteristic	Unit	Maximum permissible Concentration Category 1	Category 2	Category 3
A2.1.1	General				
A2.1.1.1	Suspended Matter (turbidity)	mg/l (as SiO_2)	discharge of effluents shall not cause formation of sludge or scum in the receiving water.		
A2.1.1.2	Colour	number (pt-Coscale)	discharge of effluents shall not cause any change in the natural colour of the receiving water.		
A2.1.1.4	Temperature	^{0}C	discharge of effluents shall not raise the temperature of the receiving water by more than 5^{0}C		
A2.1.1.5	Total dissolved solids	mg/l	2,000	2,000	No Limit.
A2.1.1.6	pH	—	6.5-8.5	6.5-8.5	6.5.9.0
A2.1.1.7	Dissolved oxygen	mg/l	6	5	3
A2.1.1.8	Oxygen solution	%	80	60	40
A2.1.1.9	B.O.D—5days 20^{0}C	mg/l	5	5	10
	—5days 25^{0}C	mg/l	6	6	11
	—5days 30^{0}C	mg/l	6	6	— 12
	—5days 35^{0}C	mg/l	7	7	13
A2.1.1.10	Permanganate Value	mg/l	20	20	
A2.1.2	Inorganic Substance	mg/l			
A2.1.2.1	Aluminium (AL)	mg/l	0.3	0.3	0.5
A2.1.2.2	Arsenic (AS)	mg/l	0.05	0.1	0.1
A2.1.2.3	Barium (Ba)	mg/l	1.0	1.0	1.5
A2.1.2.4	Boron (B)	mg/l	1.5	1.5	1.5
A2.1.2.5	Cadmium (Cd)	mg/l	0.05	0.1	0.2
A2.1.2.6	Chromium 111 (Cr3+)	mg/l	0.1	0.3	0.5
A2.1.2.7	ChromiumVI (Cr6+)	mg/l	0.05	0.1	0.1
A2.1.2.8	Cobalt (Co)	mg/l	0.1	0.1	0.5
A2.1.2.9	Copper (Cu)	mg/l	3.0	3.0	4.0
A2.1.2.10	Iron (Fe)	mg/l	1.0	1.2	1.5
A2.1.2.11	Lead (Pb)	mg/l	0.1	0.1	0.2
A2.1.2.12	Manganese (Mn)	mg/l	0.5	0.8	0.8
A2.1.2.13	Mercury (Hg)	mg/l	0.001	0.001	0.005
A2.1.2.14	Nickel (Ni)	mg/l	0.05	0.05	0.1
A2.1.2.15	Selenium (Se)	mg/l	0.05	0.05	0.5
A2.1.2.16	Silver (Ag)	mg/l	0.05	0.05	0.05
A2.1.2.17	Tin (Sn)	mg/l	0.5	0.5	0.1
A2.1.2.18	Vanadium (V)	mg/l	0.005	0.005	0.01
A2.1.1.19	Zinc (Zn)	mg/l	0.2	0.2	0.1
A2.1.2.20	Ammonia + Ammonium (NH3+NH4)(3NH+4NH)	mg/l	0.5	0.5	2.0
A2.1.2.21	Chlorides (CI)	mg/l	200	200	400
A2.1.2.22	Fluorides (F—)	mg/l	8.0	8.0	8.0
A2.1.2.23	Cyanides (CN)	mg/l	0.05	0.05	0.1
A2.1.2.24	Nitrates (NO_3) NO_3-	mg/l	50	50	00
A2.1.2.25	Nitrites (NO_2) (NO_2)	mg/l	as low as is required to prevent eutrophicationor excessive weed growth if nitrogen is a limiting		
A2.1.2.26	Phosphates PO_4---	mg/l	nutrient in waters which are susceptible to eutrophication or excessive weed growth, or in rivers and streams draining into such waters, the lowest possible concentration should be aimed as if phosphorous is a limiting nutrient.		
A2.1.2.27	Sulphates SO_4-	mg/l	600	600	600
A2.1.2.28	Sulphides (S—-)	mg/l	0.01	0.01	0.1--
A2.1.3	Origanic Substances Alkyl benzene Sulphonates (ABS)	mg/l	0.5	1.0	1.0
A2.1.3.2.	Aromatic and aliphatic hydrocarbons	mg/l	0.05	0.05	0.1
A 2.1.3.3.	Aromatic nitrogen containing compounds (e.g. aromatic amines)	mg/l	0.01	0.01	0.1
A2.1.3.4	Chloroform extra (CE)	mg/l	0.5	0.5	1.0
A2.2.1.3.5	Formaldehyde	mg/l	0.2	0.2	0.5
A.2.2.1.3.6	Grease and oils (petrolium ether extract)	mg./l	0.5	1.0	5.0
A2.1.3.7	Non-volatile chlorinated compounds	mg/l	0.005	0.005	0.01
A2.1.3.8	Volatile chlorinated hydrocarbons (CI)	mg/l	0.005	0.005	0.01
A2.1.3.9	Organchlorine pesticides (CI)	mg/l	0.0005	0.0005	0.001
A2.1.3.10	Other pesticides	mg/l	0.001	0.001	0.005
A2.1.3.11	Phenols	mg/l	0.002	0.002	0.1
A2.1.3.12	Resins, tar etc.	mg/l	0.1	0.1	0.5

SECOND SCHEDULE

Temporary Effluent Standards

	Substance/Characteristic	Unit	Maximum Effluents meant for direct discharge into receiving waters	permissible value Trade and Industrial Effluents meant for indirect, discharge into receiving waters eg. via a munici-pal sewage treatment plant
A2 2.1	General			
A2.2.1.1	Suspended solids	mg/l	not to cause formation of sludge or scum in the receiving water	No limit
A2.2.1.2	Colour	Number (Pt-Co)	not to cause any change in the natural colour of the receiving water	100
A2.2.1.3	Taste and odour		not to cause any change in the natural taste or odour of the receiving water	No limit.
A2.2.1.4	Temperature	°C	not to cause any increase of the receiving water by more than 5°C	35°C or not more than 5°C above ambient temperature of the supplied water, which ever is greater.
A2.2.1.5.	Total dissolved solids	mg/l	3000; No restrictions for discharge into the sea.	7,500
A2.2.1.6	PH		6.5—8.5	
A2.2.1.7	B.O.D. 5 days, 20°C	mg/l	30	
	B.O.D. 5 days, 25°C	mg/l	34	No limit
	B.O.D. 5days, 30°C	mg/l	37	No limit
	B.O.D. 5days, 35°C	mg/l	40	No limit
1.8	Permanganate value	mg/l	80	No limit
	Inorganic Substances			
A2.2.2.1	Aluminium (AL)	mg/l	2.0	5.0
A2.2.2.2	Arsenic (As)	mg/l	0.1	0.1
A2.2.2.3	Barium (Ba)	mg/l	1.5	3.0
A2.2.2.4	Cadmium (Cd)	mg/l	0.1	0.1
A2.2.2.5	Chromium—III (Cr)	mg/l	0.1	2.0

	Substance/Characteristic	Unit	Maximum Effluents meant for direct discharge into receiving Water	permissible Value Trade and Industrial Effluents meant for indirect discharge into receiving waters eg. via a munici-pal sewage treatments plant.
A2.2.2.6	Chromium—IV (Cr)	mg/l	0.1	0.2
A2.2.2.7	Cobalt (Co)	mg/l	1.0	1.0
A2.2.2.8	Copper (Cu)	mg/l	0.1	1.0
A2.2.2.9	Iron (Fe)	mg/l	3.0	5.0
A2.2.2.10	Lead (Pb)	mg/l	0 2	0.2
A2.2.2.11	Manganese (Mn)	mg/l	3.0	5.0
A2.2.2.12	Mercury (Hg)	mg/l	0.005	0.005
A2.2.2.13	Nikel (Ni)	mg/l	0.2	0.5
A2.2.2.14	Selenium (Se)	mg/l	0.5	1.0
A2.2.2.15	Silver (Ag)	mg/l	0.1	0.1
A2.2.2.16	Tin (Sn)	mg/l	2.0	2.0
A2.2.2.17	Vanadium (V)	mg/l	1.0	1.0
A2.2.2.18	Zinc (Zn)	mg/l	1.0	1.0
A2.2.2.19	Ammonia + Ammonium (NH_3+NH_4)	mg/l	10	No limit
A2.2.2.20	Chlorides (CL)	mg/l	800	800
A2.2.2.21	Freeclorine	mg/l	1.0	5.0
A2.2.2.22	Cyanides (Cn)	mg/l	0.1	0.2
A2.2.2.23	Nitrates (No_3—)	mg/l	50	80
A2.2.2.24	Nitrites (No_2—)	mg/l	1.0	10
A2.2.2.25	Phosphates (Po_4—)	mg/l	6.0	45
A2.2.2.26	Sulphates (SO_4—)	mg/l	600	600
A2.2.2.27	Sulfides (S—)	mg/l	0.5	1.0
A2.2.3.1	Alky benzely sulfouate ABS 9	mg/l	2.0	5.0
A2.2.3.2	Aromatic and aliphtic hydrocabons	mg/l	1.0	5.0
A2.2.3.3.	Aromatic nitrogen containing compounds (eg. aromatic amines)	mg/l	0.05	0.05
A2.2.3.4	Chloroform extract (CE)	mg/l	5.0	10
A2.2.3.5	Formaldehyde	mg/l	1.0	1.0
A2.2.3.6	Grease and oils (petroleum ether extract)	mg/l	5	20
A2.2.3.7	Non-Volatile chlorinated compounds (CIL)	mg/l	0.05	0.05
A2.2.3.8	Organochlorine pesticides (a)	(CL)	0.005	0.005
A2.2.3.9	Other Pesticides	mg/l	0.01	0.01
A2.2.3.10	Phenols	mg/l	0.2	1.0
A2.2.3.11	Resins, tar, etc.	mg/l	2.0	5.0
A2.2.3.12	Volatile chlorineted hydrocabons (CI)	mg/l	0.05	0.05