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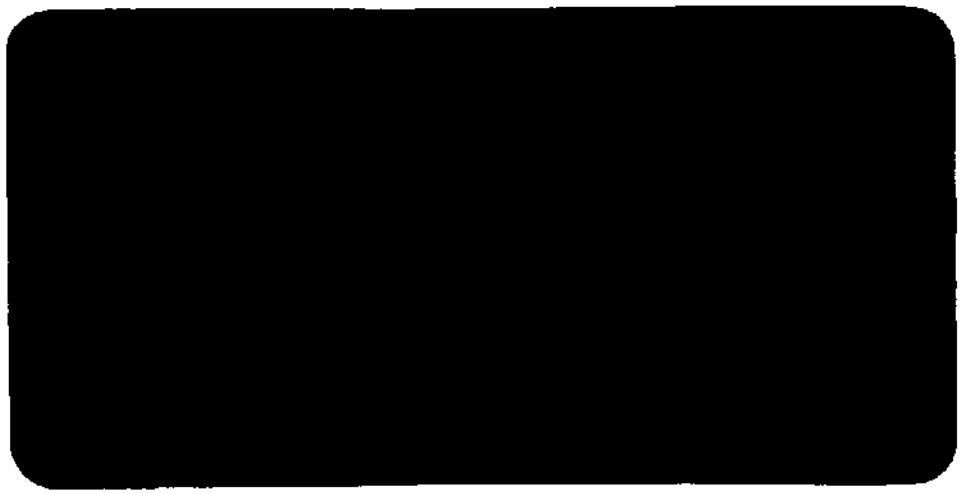

An Assessment of Common Problems Associated with Drinking Water Disinfection in the Developing Areas

Ian Pearson and Gerrit Idema

WRC Report No.649/1/98

AN ASSESSMENT OF COMMON PROBLEMS ASSOCIATED WITH DRINKING WATER DISINFECTION IN THE DEVELOPING AREAS

WRC Report

submitted to the Water Research Commission

by

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EXECUTIVE SUMMARY

Background

This project was formulated from an earlier project funded by the WRC on the assessment of alternative disinfection systems for small water supply schemes. The earlier project had identified and evaluated a number of promising alternative disinfection technologies which could be used to replace conventional chlorine disinfection systems in small remote water supply schemes. However, before these alternatives could be promoted, a decision was made by the WRC project steering committee that the actual situation with respect to the disinfection of small schemes should be assessed.

The CSIR proposed to undertake a brief study with limited funds, primarily making use of the long term water and sewage treatment plant monitoring records available at the CSIR. In addition a number of smaller schemes not monitored as part of the government support programme were visited and assessed.

Objectives

The objectives of the project were as follows:

- to establish the success or otherwise of the existing disinfection technologies in small water supply schemes in the more remote areas;
- to assess the operational constraints of these existing disinfection systems;
- to asses the extent to which disinfection of small water schemes is practised;
- to establish if the conditions in the remote community water supply areas are conducive to make use of alternative disinfection technologies where conventional disinfection systems have failed.

Results and Conclusions

A number of conclusion can be made from the study of these reports and the field visits:

- In many of the water treatment plants and small water supply schemes existing disinfection practices are unreliable and often not monitored.
- In a number of systems no chlorination is practised at all. This is usually with borehole and spring water supply schemes, although in a few cases surface water schemes are not chlorinated.

- Failure of disinfection is essentially not due to technological problems with equipment (although equipment did fail - the alternative of hand addition of chlorine was practised). The reasons for failure and unreliability of disinfection include:
  - lack of chlorine chemicals
  - lack of operator attention
  - no provision made for chlorine addition
  - lack of funds for purchasing chlorine
  - no monitoring of chlorine residual to detect chlorine levels

- It is very difficult to highlight which of the existing disinfection processes or disinfectant used is superior or inferior in these specific situations. The processes and chemicals in use include:
  - chlorine gas addition
  - dry chlorine addition (HTH) - usually by hand
  - liquid chlorine addition (HTH in solution) by drip feed or special dispenser
  - slow sand filtration

- Probably the most important aspect derived from this study is that the operators controlling the plant do not have the knowledge and understanding of the background of what they are doing, the importance thereof and the possible consequences to the community they are supposed to serve. Proper training is essential.

- In a number of cases disinfection is practised irregularly. This practise, unless based on scientific data, does not fulfil the purpose of disinfection and is a waste of time, disinfectant and money. It also creates a false sense of safety and peace of mind, whereas the community may be at considerable risk.

- In many cases there is a lack of adequate back-up to operators in terms of consumables, repairs and back-up facilities.

- Generally the concentration of the disinfectant is not measured regularly or not at all. This lack of monitoring results in the operators not being aware of the situation of the water being supplied, and not knowing when there may be problems or shortcomings in the disinfection system.

- The prime objective of disinfection is to kill harmful micro-organisms which could be present in water. Generally there is no monitoring for such micro-organisms (faecal coliforms) to determine if the disinfection process is effective or not.

Assessment of success of the project

This assessment enabled the research team to identify the approach and some of the main requirements for successful disinfection of small schemes. In particular it has identified that operator training and the provision of monitoring facilities are required as a matter of priority at most small schemes.

In terms of the original objectives, these were attained through the study. However it should be noted that conventional disinfection systems could be more successful if an improved approach and training of operators were to be commissioned. Hence whereas certain conditions do appear to favour the use of alternative systems, in the majority of cases better management is essential for both conventional chlorine disinfection systems and for the alternatives.

The alternative disinfectants (on-site production) do appear to have merit in the more remote areas where it is difficult and costly to obtain chlorine chemicals. Ultraviolet disinfection is however not recommended due to the need for maintaining a residual in the distribution systems and in the household water storage containers.

This study has provided some of the criteria for ensuring a more sustainable and reliable approach to disinfection of small water supply schemes.

Recommendations

From this study the following recommendations are made:

- From this study it is recommended that a brief handbook on disinfection for small schemes be compiled. The existing technical guide of the CSIR can be used as a basis for this, but the operator training and monitoring aspects should be added.

- Secondly, it is recommended that some of the alternative disinfection technologies, particularly the on-site generation from salt of chlorine and/or mixed oxidants be evaluated in a selected few small schemes, and the operational parameters be established.

- The information from this report, the handbook, and any further studies be distributed to relevant authorities.

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The information and research in this report emanated from a project funded by the Water Research Commission and entitled:

"An assessment of common problems associated with drinking water disinfection in the developing areas"

No steering committee was established for the project in view of the short term nature of the study.

The financing of the project by the Water Research Commission and the contribution of the research manager, Mr G. Offringa, is gratefully acknowledged.

The project was only possible with the support and co-operation of a number of organizations and individuals. The authors wish to record their sincere thanks to the following:

Department of Water Affairs and Forestry for access to the plant records of the water and sewage treatment plants in the developing areas.

These plant records have been collected and are stored and maintained by the Water Care Group of the Division of Water, Environment and Forestry Technology, CSIR. The co-operation of Mr JS Wium is gratefully acknowledged.

The water committees of all communities visited.

The Department of Health officials at Ndwedwe and at Nseleni/Ongoye in KwaZulu/Natal who facilitated contact with the community water committees and the water supply schemes.

The Department of Agriculture officials in Hlabisa in KwaZulu/Natal who facilitated contact with the Hlambanyathi community.

1. INTRODUCTION

Disinfection is a very important step in the treatment of drinking water in order to prevent or reduce the risk of waterborne diseases. However, it has been reported that in many cases in the developing countries a high level of reliability of water supply schemes, particularly the treatment process, is the exception rather than the rule. This could be contributed to various factors which include cost, operator training and knowledge, and problems with the maintenance of the infrastructure.

Various types of pathogenic microorganisms which include bacteria, fungi, protozoa, parasites and viruses may be present in raw water sources. These microorganisms pose a potential risk to human health (Rao and Melnick, 1986). Cholera, typhoid and gastroenteritis caused by these organisms are amongst the important water borne diseases. The importance of water in the transmission of diseases in humans is highlighted by the World Health Organization (WHO) who claim that 25% of all the world's hospital beds are occupied by people with diseases caused by polluted water or water-related diseases (WHO, 1976). More recently it was claimed that 50 000 people, (33,3% of the people that die each day in the world), die of water related diseases (Schalekamp, 1990).

This study was initiated to establish the extent to which drinking water supply systems are chemically disinfected in the rural and developing areas of South Africa. The study involved a limited assessment of the efficiency and reliability of disinfection systems where they exist, and the common problems associated with the systems being used. The result of this study would be used to propose new design standards or the use of alternative disinfection systems to overcome these problems and to increase the reliability of disinfection of water supplies in the developing areas.

2. METHODOLOGY

The assessment comprised two components. The first was a study of existing water treatment plant records, and the second was a field evaluation of selected water treatment facilities in small communities. The existing plant records were from CSIR reports of the long term monitoring of water and wastewater treatment plants in the developing areas of South Africa, while selected field evaluations of community water supply schemes which were not being monitored were undertaken in the Northern Province and in KwaZulu/Natal.

2.1 Study of water treatment plant records

The information was gathered from monitoring reports from three provinces over the past three years. The reports were compiled by the Division of Water, Environment and Forestry Technology, CSIR. These reports cover the more formal water supply schemes in the developing areas of each province. Various sample locations have been monitored over the years in these areas with one or more sampling site at each location.

The reports have been screened to identify:

(a) the location and number of samples analysed from a specific location,
(b) whether chlorination is being applied,
(c) the type of chlorination system used,
(d) problems associated with the disinfection,
(e) if the chlorine level is monitored, and
(f) whether the bacteriological quality is monitored by means of the faecal coliform count.

The results are summarised in tables (section 3), and from these the main conclusions were drawn.

2.2 Assessment of situation at small community managed systems

A number of communities with small water supply schemes which are not being monitored were visited in the KwaZulu/Natal and Northern Provinces. These water supply schemes were assessed in terms of the disinfection practices and parameters as for the long term monitoring reports.

3. SURVEY RESULTS
(Water Treatment Plant Records)

The observations from the water treatment plant reports are provided in table form under the different regions where CSIR monitoring has taken place. Only records of the 3 years 1993 to 1996 are reported here.

3.1 Eastern Cape (previous Ciskei region)

Conventional drinking water treatment systems

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform /100mℓ	Problems / Comments
Glenmore	4	0.1 - 0.2	0	Functioning well
Middeldrift	4	-	0	Gas chlorination
SADA	16	< <0,1	0 - 2	Only 1 Cl_2 reading; generally good quality
Zwelisha Town	9	<0,1-	-	Gas chlorination; turbidity problems
Moantsane	58	> >1,0	0 - >1000	FC in ± 40% of samples and no Cl_2 present
Masincedame	21	<0,1 - 0,2	-	Gas chlorination; good quality water supplied
Tyefu	22	-	505 (once) 0	Acceptable water quality
Dubi	6	-	0 - 23	-
Seymore	41	0 - 0.3 < <0,1		Usually no Cl_2 added; HTH used occasionally; no qualified people; chemicals not always available
			0 - 98	Equipment broken. HTH shock dosage occasionally
Upper Mnyameni	19	-	0 - 2	HTH shock dosage only
Upper Gxulu	20		(-) - 0	Irregular HTH dosing; FC tested occasionally; all
Phlanduiwazi	52	(-) - <0,1 (-) - 0.2	0 - 4	were negative. Generally poor quality; no Cl_2 dosage
St. Thomas School	24		(-) - 0	Hypochlorite addition not regular
Mpofu	18	0	-	No chlorination
St. Mathews Hospital	48	(-)- <0,1	>10 (twice)	Water quality fluctuations
Fish River Sun	57	-	-	-
Katberg Holiday Resort	1	<0,1 (twice) -		

Borehole (B) and River water (R) (no treatment except chlorination)

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Ntabethemba (B)	9	-	-	Acceptable - good quality water; No Cl_2 or FC
Moatsane (R)	12	-	-	Acceptable - good quality water; No Cl_2 or FC
St. Mathews College (B)	7	(-) - 0	(-) - 244	

Sewage Treatment (E. Cape)

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Zwelisha Town	21	(-) - 0.1	(-) - 15	In general not conforming to standard
Moantsane	74	(-) - 0.1	(-) - > > pos	Effluent not conform to standard: almost no Cl_2 or FC monitoring
Potsdam	31	-	-	Cl_2 not monitored: effluent in good condition
Keiskammahoek	7	-	-	Effluent not acceptable to Standard
Fort Cox Agric. College	3	-	-	Ponds may be overloaded
Fort Hare University	17	-	-	Chlorinated once; generally good quality
Lovedale College	14	-	-	Generally poor quality; No chlorination;
Tamara Police Station	1	-	(-) - 72000	No chlorination
Healdtown	1	-	-	-
Rocklands	8	-	-	No chlorination due to mechanical problems
Mt Coke Community Health Centre	40	-	-	No operator; too high load, sometimes in good shape; has a chlorinator in place
Fish River Sun	11	-	-	Hypochlorite dosing, no monitoring; generally good effluent

Orbal Disc Aeration

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Ilitha Dorp	10	-	-	Not operational; poor quality water; no indication of Cl_2 or FC testing

3.2 GENERAL COMMENTS ON EASTERN CAPE (CISKEI)

i. Gas chlorination is applied more often than any other form of chlorination at the conventional water treatment plants.

ii. The levels of free and total chlorine in drinking water were monitored very irregularly by operational staff. At many stations no chlorine level measurements were reported at all (refer to tables).

iii. Almost no faecal coliform counts were reported in drinking water samples, although the water quality was stated many times as good, excellent etc.

iv. When high faecal coliform counts were reported occasionally, **no** chlorine levels were reported.

v. Water quality is measured in many instances in drinking water treatment plants just on turbidity, and at sewage treatment plants as COD, OA, chlorides, ammonia and O_2 absorbed.

vi. Although it is mentioned often that wastewater is chlorinated, chlorine in the wastewater is almost never tested.

vii. Residual chlorine levels where measured are at the low level (usually <0.3mg/ℓand often <=0.1mg/ℓ). These measurements are at the end of the treatment process, and hence there is little protection against recontamination in the distribution system or in the household water collection and storage containers.

3.3 NORTHERN PROVINCE (previous Lebowa region)

Conventional Drinking Water Treatment Systems

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Mapulaneng	2	<0.1 - 0.6	0	-
Ramodike Mogobaya	3	0.4 - 1	0-75(once)	Faecal polluted
Moganyaka	3	0.1 - 1.6	0-40(once)	Gas chlorination; good quality
Olifantspoort	6	0.2 - 1.4	0	Good quality water
Seshego	25	<0.1 - 1.8	0	Good quality water; Mostly HTH chlorination
Gagkapane	2	0.3	0	-
Motetema	3	0.2 - 0.6	0	-
Namakgale	1	-	0	-
Sekozosa Hospital	3	0.1 - 0.8	0	-
Helen Franz Hospital	1	0.1	0	Hypochlorite added periodically
George Nusebe Hospital	2	2.2	0	Gas chlorination
Mahwelereng	1	-	polluted	**No chlorine gas**
Maukweng	10	0.5 - 1.2	0-1	Water supplied by Dept. Water Affairs
Blouberg Hospital	1	0.1	0	Hypochlorite added periodically
Shatali	1	0.2	0	Hypochlorite added periodically
Vergelegen	1	0.7	0	Hypochlorite added to reservoir
Lenyenye	10	0.4 - 1.2	0	Gas chlorination
Matlala Hospital	2	0 - 3	0	Gas chlorination
Hrogotlow	7	<0.1 - 1.4	0	-
Tompi Selekka Agr. Col.	5	<0.1 - 1.6	0-400(once)	No chlorine for 3 weeks; doser out of order
Molepo	6	0.1 - 0.4	100-600 (2X)	Hypochlorite not available
Lebowakgomo	4	0.2 - 0.7	0	Hypochlorite; not always available; polluted
Penge	1	-	0	-
Acornhoek	3	<0.1 - 0.4	0-100(once)	Hypochlorite
Van der Merwe straat	2	<0.1	80-100	HTH every 8 hours

Boreholes

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Mahwelereng	1	0.1	0	-
Scoonoord Clinic	1	<0.1	0	-
Penge	1	-	200 - 300	-
Sibayeng	3	0	0-26 (once)	HTH added once a month

Sewage Treatment - Stabilization Pond

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Mapulaneng	1	-	250	Outside effluent standard
Lenyenye	3	-	-	Not overflowing
Moganyaka	3	0-6	-	Hypochlorite drip feeding
Moletema	2	-	-	No effluent
Sekososo Hospital	3	-	-	**No Hypochlorite**
Helen Frenz Hospital	2	-	>1000	-
George Masebe Hospital	2	-	>1000	Hypochlorite added
Mahwelereng	2	-	>1000	Hypochlorite added: no flow meter
Blouberg Hospital	1	-	-	No discharge
Mutlula Hospital	2	3	0	Hypochlorite drip feeding
Tubatse	2	0,2-1,0	0	-
Hlogothou	1	-	-	No effluent
Saliquefiflow	1	-	16	No treatment
Gane furse	2	-	800 - 860	HTH: 1,2Kg / day
Tompi Seleke Agr. Coll.	2	-	<1000	-
Lebowakgomo	1	-	10 000	-
Penge	1	-	-	Chlorinator & gas bottles removed
Acornhoek Police Station	2	-	250 - >1000	No disinfection

Sewage Treatment - Biological Filtration

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Gagkapane	1	-	> 1000	Gas chlorination
Seshego	21	-	200 - >1000	No disinfection or flow meters
Namakgale	4	0	850-1200	Infrequent disinfection
Maukweng	12	-	0 - <1000	Advanced disinfection equipment installed but not used

3.4 COMMENTS: Northern Province (previous Lebowa region)

I. With the same amount of chlorine introduced on a daily basis, the faecal coliform counts vary between 0 and 40 to 70/100mℓ. This indicates the varying quality of the waters treated, and hence that chlorine dosing should be tested for site-specific demand characteristics.

ii. The impression is created that gas chlorination has proved to be somewhat problematic, and it is often replaced by HTH (calcium hypochlorite) dosing. A number of problems have been reported with regard to dosing equipment.

iii. It has been reported on occasions that at some plants no chlorine gas has been available for disinfection at the time of inspection, and in some cases where calcium hypochlorite is used, no HTH has been available.

iv. It is noted from the reports that in the cases where problems with the microbiological quality of the water exists, no or irregular disinfection has been applied.

v. At some of the plants, the microbiological (faecal coliform counts) quality have been very good on a large number of visits, indicating good control of the treatment process.

vi. Chlorine levels are generally much higher than at the plants monitored in the Eastern Cape, with a measurable residual in the water entering the distribution systems.

3.5 KWAZULU/NATAL

Conventional Drinking Water Treatment Systems

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Umlazi reservoir	24	0.1-0.2	0	Regularly monitored; good quality water
Kwadabeka	18	0.1	0	Gas chlorination; not regularly monitored
Kwamakhuta	27	0.1-0.2	0-15	Frequently monitored for Cl_2; FC detected
Magabeni	64	0.2	0 (once)	Chlorine applied; poorly monitored & tested
Gamalakhe	22	0.1	0	Gas chlorination; generally good water quality
Mpumalanga	3	0.2	0	Good water quality
Sundumbili	50	1.8	0	Gas chlorination
Ngwelezana	54	2.7	0-11	Gas chlorination
Vuleka School for Blind	18	<0.1-1.5	0	Hypochlorite chlorination
Impendle	2	0	67	No treatment or chlorination
Table Mountain	1	0	0	No chlorination
University of Zululand	37	<0.1-2.3	0	Gas chlorination; good quality water
Edendale Tech. College	3	0.1	0	Gas chlorination
Amanzimtoti Coll. Educ.	30	<0.1	0	chlorination
Vukile High School	29	0.1-3.8	0-127	FC detected when free Cl_2 <0.1
Adams Mission Agric.	3	0-0.1	0-229	-
Belgrade	17	0.1	0	Hypochlorite dosing
Swartkops Agric. Depot	11	0	0-11	Chlorman chlorinator; chlorine basket; No Cl_2
Nyangwini	10	<0.1	0-130	-
Erith Trust Forum Agric.	7	0	0	No chlorine applied; FC appear to be 0
Ridges Trust Agric. Depot	8	0	0-44	No chlorine applied
Manzengwenya	7	<0.1	0-95	-
Mbazwane Forestry	17	0-0.4	0-60	Hypochlorite dosing;
Vuma Youth Camp	36	0,1-1.2	0	Hypochlorite dosing
Musi Border Post	2	0.1	0-6	Cl_2 not available; Hypochlorite dosing
Maputa Police Station	9	0	0-6	No chlorine applied
Mbongolwane Hospital	9	0-1,2	0-6	Hypochlorite dosing
Catherine Booth Hospital	21	<0.1-1,5	0-23	Hypochlorite dosing; When FC present no Cl_2
Nkonjeni Hospital	46	0-1,5	0-200	Gas chlorination; 0 Cl_2; frequently polluted FC
Hlubisa Hospital	43	0	0	Hypochlorite; FC irregularly test; good quality
Bethesda Hospital	53	0-4,0	0	Gas chlorination; No DPD tablets
Manguzi Hospital	56	<0,1	0-400	Gas chlorination; No gas or HTH available
Mosvold Hospital	33	<0.1	0	Hypochlorite dosing
Mseleni Hospital	13	<0,1-0,2	0	Gas out of order; No Hypochlorite available
Murchison Hospital	7	<0,1-0,2	0	-
Untumjambili Hospital	13	<0,1	0	-
Kwabadala Old Age Home	19	<0,1	0-43	No Hypochlorite available
Nkandla Hospital	12	2,5	0	Hypochlorite dosing
Ekombe Hospital	14	>0,1-4.0	0-17	HTH tablets
Appelsbosch Hospital	74	0-0,5	0-118	Switched HTH to gas, Irregular dosage & moni No
Ehlanzeni Clinic	9	0-2,0	11-225	Cl_2; FC in all cases
Montebello Hospital	54	0-2.0	0-12	Hypochlorite; No Cl_2 detected FC present
Ceza Water Supply	62	<0,1-4.0	overgrow	Hypochlorite; FC without Cl_2; generally good
Thaslesizwe Hospital	25	0.1-2,0	0	Hypochlorite; generally good quality water
St. Francis Hospital	15	<0,1-2,0	0	No record of how Cl_2 is applied
St. Appolinaris Hospital	19	0,1-0,8	0	18 HTH tablets/day in chlorinator; No FC
Ekapumuleni Hospital	27	0-1,5	0-79	HTH; Inconsistent dosing; frequent FC detect
Luwamba Hospital	13	0-0,9	0-9	Hypochlorite; FC when no Cl_2 detected
Benedictine Hospital	2	-	0	Chlorination facility not used
Umpumulo Hospital	60	0-4	0-203	Hypochlorite; FC in ± 15 of samples = No Cl_2
Itshelejuba Hospital	16	0-0,2	0-35	Gas out of order, HTH used; frequently FC
Amalikulu Old Age Home	8	0	0-10	No Cl_2 dose or detect; Eshowe water; FC detect
Assisi Hospital	24	0	0-5000	HTH; FC detected frequently when no Cl_2
Ekuhlengeni Senatorium	3	0	0	No FC or Cl_2; Amanzimtoti water
Oxindisweni Hospital	17	2,6	0	Gas chlorination + one Standby; No FC detect No
Umgababa Pleasure Resrt	4	0	154	Cl_2; FC detected once
Nongoma	42	0-1,5	0	Gas empty - used Hypochlorite; No FC
Izingolweni Magistrate	12	0	0	No chlorination
Ndedwe	3	2,5	0	-
Mahlabathini	6	0	0-1000	Hypochlorite
Umbumbulu	11	0-0,8	0	Hypochlorite

Conventional Drinking Water Treatment Systems (continued)

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Ulundi	49	0-1,5	0	Gas chlorination, blockages in pipeline
Kwakangella	13	1.0	0	Hypochlorite dosing
Southern Region Works	17	0-0,3	0	-
Ndwedwe Magistrate Camp	10	1	0	Hypochlorite dosing
Olifantskop Water supply	38	<0.1-1.0	0	-
Ncibidwe Clinic	2	0-0,3	0-240	-
Mazizin Clinic	16	0	0-700	Hypochlorite: >50% of samples FC polluted
Oliviershoek	2	0	0-380	-
Enthembini Clinic	14	0	0-200	>70% of samples FC polluted
Kwamsale	4	0,1	-	-
Enseleni	27	0,1-3,5	-	Acceptable quality
Kwamsane	13	(-)-1.0	(-)-80	Contaminated effluent from stabilization pond
Mpungamhlope	17	<0.1-0.4	(-)-9	Acceptable quality without disinfection
Ncotshane	5	<0,1-0,1	-	Water from Pongola
Mfolweni	7	(-)-<0,1	(-)-98	Often reported contaminated:not for human use
Mpophomeni	12	(-)-0,2	-	Acceptable quality; well operated
Wembezi	6	(-)-0,1	0	Generally acceptable
Ezakheni	21	0,2	-	Acceptable water quality
Hlamgamani	8	0,1-0,6	-	Acceptable water quality
Limehill	16	<0,1-0,2	(-)-340	Corrosive: acceptable: polluted water
Osizweni	8	0,1	0	Acceptable water quality
Madadeni	8	<0,1-0,1	(-)-0	Acceptable quality
Momdla	9	0,8	-	Acceptable quality
Frischsewaagd	1	1,5	1	FC contaminated. fit for use
Pungashe	1	-	>10	Contaminated
Dududu	2	0-<0,1	-	Acceptable quality
Mhlumayo	1	0,4	-	Not operational
Tugela Ferry	2	0,2	0	Acceptable quality
Mtuzuma	3	0,1	0	Water supplied by Umgeni; acceptable
Ekuvukeni	2	(-)-0,4	0	Acceptable quality
Kwamdengezi	3	<0,1	-	Acceptable quality
Moguhtia	1	<0,1	(-)-0	Acceptable quality
Snating	1	0	0	Acceptable quality
Esikmawihi	9	0,7-2,5	0	Acceptable quality
Momdweni	2	0,2	0	Acceptable quality
Jozini	4	0,3	0	Acceptable quality
Nqutu	3	<0,1	0	Acceptable quality
Kwamboma	6	<0,1	0	Acceptable quality
Mahlabathini	1	0,2	0	Acceptable quality

Boreholes

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Dept. Agric. & Forestry	18	-	38	FC & Cl_2 tested once and polluted
Emmaus Hospital	9	0-2,0	0-65	FC when no Cl_2 detected
Mangeni Clinic	1	0	0	No Cl_2
Kathla Clinic	1	-	0	-
Cwaka Clinic	12	0	3	No Cl_2
Mazabeko Clinic	1	-	0	No Cl_2

Sewage Treatment (KwaZulu/Natal)

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Umlazi Sewage Works	40	0-0,4	-	Gas chlorination. No FC tested, good quality
Kwadabeka	6	0-0,2	-	Gas chlorination
Kwamakkuta	15	0,1	-	Gas chlorination; effluent does not comply
Magabeni	38	< <0,1	-	Hypochlorite drip; Cl_2 less 0,1 mg/ℓ
Mpumalanga	26	,0,1	-	Gas chlorination; generally good effluent
Sundumbili	50	1,2	-	Gas chlorination; poorly monitored; No FC
Gezinsila	13	-	-	No chlorination or FC; effluent generally poor
Ngwelezane	45	2,5	-	HTH drip; good quality effluent; No FC tested
Vuleka School for blind	5	0-0,4	-	-
University of Zululand	43	0-1,5	-	Gas chlorination + standby unit; No FC; Good
Edendale Technical Coll	11	2,0	-	Hypochlorite drip
Amanzimtoti Coll. of Educ	37	0-1,5	-	Gas chlorination; HTH
Mbongolwane Hospital	19	-	-	-
Catherine Booth Hospital	7	-	-	Acceptable quality; no or little effluent
Hlubisa Hospital	7	0-0,2	0-33	-
Bethesda Hospital	27	0-1,0	-	Gas chlorination
Manguzi Hospital	3	0	-	-
Murchison Hospital	33	0-4,0	0	Hypochlorite; Not tested for FC
Untanjambili Hospital	10	-	-	-
Nkandla Hospital	5	-	-	-
Charles Johnson Me Hosp	49	7,2	0-2500	Hypochlorite; 7FC at 4mg Cl_2; variation Cl_2 level
Appelsbosch Hospital	15	0,1	0-14	Hypochlorite dosing
Emmaas Hospital	27	0-1,5	50 000	Cl_2 ans FC not often tested
Montebello Hospital	30	-	-	Cl_2 and FC not tested
Ceza Water	25	-	-	Cl_2 and FC not tested
St. Francis Hospital	9	-	-	Not tested for Cl_2 although used
St. Appolinaris Hospital	18	0-0,1	-	FC not analysed
Benedictine Hospital	2	-	-	Chlorination but not measured
Itshele Juba Hospital	4	0	1000	-
Amatikula Old Age Home	5	-	-	-
Assisi Hospital	34	-	-	No FC or Cl_2
Ekuhlengeni Senatorium	8	1,5	-	Hypochlorite dosing
Osindisweni Hospital	14	1	-	Gas chlorination
Nongoma	6	-	-	-
Ulundi	38	0,2	-	-
Hlangani	3	-	-	-
Enseleni	3	1,4	-	Acceptable
Kwamsane	5	1,0	-	Contaminated
Wembezi	6	0,1	-	Acceptable
Madademe	9	0,1	-	Acceptable
Kwamdemgezi	1	<0,1	-	Acceptable

3.6 COMMENTS: KWAZULU/NATAL

I. All the commercial forms of chlorine, i.e. gas, sodium hypochlorite, calcium hypochlorite and chlorine tablets, are used for disinfection of water in KwaZulu/Natal.

ii. Where chlorine is applied, the presence of a residual in the water is often not monitored or poorly/infrequently monitored.

iii. In a number of instances faecal coliform counts are monitored irregularly or in some instances not at all.

iv. In the case of the Ehlanzeni Clinic, faecal coliforms were detected in all the nine samples tested but no chlorine was detected at any stage.

v. Standby chlorination facilities do not exist except for a few exceptions.

vi. The impression is created that the majority of sewage effluent is chlorinated. However, the level of chlorine in the effluent is not monitored regularly. Faecal coliform counts in the effluent are determined only in a few cases.

vii. It is noteworthy that in the majority of cases where faecal coliforms were detected, no chlorine was detected at that time.

viii. In a number of plants it has been reported that chlorine stocks have run out and that no chlorination is applied for a period.

ix. In many instances where chlorination is applied, the residuals leaving the treatment plant are low, providing little or no protection to the distribution system or household collection and storage containers.

3.7 MPUMALANGA (previous Kangwane region)

Conventional Drinking Water Treatment

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Mkwakweni	20		18	-
Matsula	111	0.1-3.8	(-)-0	No chlorine for a week; chlorinator broken
Nkwalini	18	≤2.5	0	-
Kamaghekeza	49	0.1->4,0	0	-
Kromdraai	11	(-) - 0.7	(-)-≤600	-
Mpuluzi	188	<0.1- 2.6	(-)-≤900	-
Kabokweni	92	0.1-2.5	(-)-25	Gas Cl_2 out of order. HTH when available
KaNyamazane	102	(-)-2.6	(-)-0	-
Louieville	33	(-)-0.4	0-≤65	-
KaMhluswa	3	0.2-0.9	≤5	-
Matoulo	104	0.1-4.0	0-1100	-
Pienaar/Saantjie	24	-	0	-
Clan-clan	24	-	0	-
Swaleni	24	-	0	-
Mpumalanga	24	-	0	-
Matsulu wsw	22	-	0	-
Bengain Hospital	3	-	0	-

Borehole Drinking Water

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Louieville	26	-	(-)-0	-

Sewage Treatment

Place	No of samples tested	Range of Cl_2 residual in mg/ℓ	Range of Faecal coliform / 100mℓ	Problems / Comments
Kabokweni	29	-	(-)-8000	-
Mpuluzi	6	-	(-)-≤200	-
Louieville	51	(-)-2.5	(-)-≤2700	No Chlorine available. empty
Kanyamazane	46	0.1-1.1	-	-
Matsulu	23	-	(-)-2000	-

3.8 COMMENTS: MPUMALANGA (previous Kangwane region)

I. Chlorine is applied in some instances, but the presence of chlorine in the water is not monitored or poorly monitored.

ii. In a number of instances faecal coliform counts are monitored irregularly or in some instances not at all.

iii. Standby chlorination facilities do not exist except for a few exceptions.

iv. The majority of sewage effluents are chlorinated. However, the level of chlorine in the effluent is not monitored regularly. Faecal coliform counts in the effluent are determined only in a few cases.

v. It is noteworthy that in the majority of cases where faecal coliforms were detected, no chlorine could be detected at that time.

vi. Generally chlorine dosing is applied and chlorination facilities are available. However the reliability of supply and dosing is often a cause for concern.

3.9 DISCUSSION ON CONVENTIONAL TREATMENT PLANTS

A total of 3198 drinking water sample and 1215 sewage sample reports have been analysed in order to determine whether problems are reported with regard to disinfection and the type of disinfectant and process used.

The results compiled from the reports in this study clearly indicate that only chlorine, either in the gas or hypochlorite form is used for the disinfection of potable water.

Only a small number of places from the various regions have been using chlorine gas. Analysing the faecal quality of such gas chlorinated water indicate in some instances water to be continuously free of faecal coliforms whereas in some instances frequent faecal pollution occurred. The level of disinfection achieved depends on the dosing level, and the level of operator care, particularly regarding residual testing and the timely ordering of stocks.

Hypochlorite (as Calcium hypochlorite) has been used in most instances where disinfection was applied. At a number of stations throughout the regions, faecal coliforms have been reported at numerous occasions without any chlorine being detected or added. At other stations, it is recorded that chlorine is added without analysing the level of chlorine present in the water or the faecal coliform count. It has been reported only in a few instances that no chlorine was available or that the equipment was not operational. Only at the University of Zululand, a standby chlorination unit is available.

The dosing of hypochlorite is undertaken either by continuous drip feed, or by timed additions to a reservoir. On occasions the drip feeders block, or vary the dose depending on the level in the make-up tanks, while operator commitment to chlorine addition to reservoirs may be questionable, particularly since many plants only have an operator on duty in the day, and in some instances not over weekends.

Sewage effluents are reported to be disinfected by either chlorine gas or hypochlorite. The amount of chlorine or the faecal coliform count in the effluent has frequently not been monitored. Disinfection of wastewater only serves a purpose when enough chlorine is introduced to kill off all the bacteria present. Domestic effluent consist of numerous substances which are used by bacteria as part of their basic food requirements. Bacteria which are not killed by the disinfection remain in the effluent and may multiply in favourable conditions to even similar levels to those before the disinfection process.

An important distinction between hypochlorite and chlorine gas is that the reaction of chlorine gas and water decreases the alkalinity, or pH balance, while the reaction of water and hypochlorite does not alter the pH. This is an advantage of using hypochlorite in small water systems where the water is often corrosive to metal pipes and fittings.

4. FIELD VISITS TO SMALL WATER SUPPLY SYSTEMS

A number of small water supply schemes were visited (in addition to those more formal schemes already listed above which are visited on a regular basis by CSIR). The additional schemes visited were for the most part community managed schemes which do not have any government or municipal authority to support them. These could be divided into three basic groups:

- those which use boreholes as a water source;
- those which use springs as a basic water source;
- those which use surface water (streams and dams) as a basic water source.

The borehole water supplied schemes visited were in the main part in the Northern Province, while the springs and surface water supplied schemes were in KwaZulu-Natal. The following findings can be reported from the visits:

I) Borehole Water Schemes

None of the 8 schemes visited add any chlorine to borehole water supplies. In all schemes the water is pumped, either by diesel engine or electric engine driven pumps, to storage reservoirs, and then distributed to standpipes. Low levels of faecal contamination were found in most of the supplies (< 50/100ml). Communities were not aware of any problems related to non-chlorination, although diarrhoea illnesses in children are relatively common.

Schemes visited:	Seokodibeng	Southern District
	Masete	"
	Ga-Mashishi	"
	Mathabatha (Lekwareng)	"
	Tshwareng	"
	Raphahlelo	Lowveld District
	Ga-Phooko	"
	Itieleng	"

ii) Springs and Surface Water Schemes

Four of the six surface water schemes have facilities for dosing chlorine, but none of the spring supplies have any chlorine dosing facilities. In the surface water schemes with chlorine dosing equipment, none of the more complex

dosing systems were in operation, and operators had resorted to no chlorine addition, or to adding HTH by hand once per day. For all the schemes there was some microbiological protection in the form of slow sand filters or protected catchments. However, low levels of contamination of water supplies was found in these schemes.

Problems encountered with the operation of the schemes were:

- sand filters not cleaned regularly
- chlorine dosing equipment breakdowns
- lack of chemicals
- operator not properly trained
- no facility for dosing chlorine in the plant design

A notable exception was at KwaNyuswa in the Ndwedwe district of KwaZulu/Natal. This community managed scheme had a flow-proportional chlorine dosing system at the treated water pump station. The dosing system had broken down within a year of commissioning the plant, but the operator had been trained to add sufficient chlorine by hand to the treated water sump. This function had continued to be carried out daily, with the dry chlorine being purchased with community water tariffs.

Schemes visited:	Isiminya	Ndwedwe KZN
	Makholokholo	Nseleni KZN
	Hlambanyathi	Hlabisa KZN
	Mathabatha	Southern District NP
	KwaNyuswa	Ndwedwe KZN
	Masibambisane	Maphumulo KZN
	Numerous springs in Southern KwaZulu/Natal and in the Eastern Cape (Eastern Region)	

5. CONCLUSIONS

A number of conclusion can be made from the study of these reports and the field visits:

5.1 In many of the water treatment plants and small water supply schemes existing disinfection practices are unreliable and often not monitored.

5.2 In a number of systems no chlorination is practised at all. This is usually with borehole and spring water supply schemes, although in a few cases surface water schemes are not chlorinated.

5.3 Failure of disinfection is essentially not due to technological problems with equipment (although equipment did fail - the alternative of hand addition of chlorine was practised). The reasons for failure and unreliability of disinfection include:

- lack of chlorine chemicals
- lack of operator attention
- no provision made for chlorine addition
- lack of funds for purchasing chlorine
- no monitoring of chlorine residual to detect chlorine levels

5.4 It is very difficult to highlight which of the existing disinfection processes or disinfectant used is superior or inferior in these specific situations. The processes and chemicals in use include:

- chlorine gas addition
- dry chlorine addition (HTH) - usually by hand
- liquid chlorine addition (HTH in solution) by drip feed or special dispenser
- slow sand filtration

5.5 Probably the most important aspect derived from this study is that the operators controlling the plant do not have the knowledge and understanding of the background of what they are doing, the importance thereof and the possible consequences to the community they are supposed to serve. Proper training is essential.

5.6 In a number of cases disinfection is practised irregularly. This practise, unless based on scientific data, does not fulfil the purpose of disinfection and is a waste of time, disinfectant and money. It also creates a false sense of safety and peace of mind, whereas the community may be at considerable risk.

5.7 In many cases there is a lack of adequate back-up to operators in terms of consumables, repairs and back-up facilities.

5.8 Generally the concentration of the disinfectant is not measured regularly or not at all. This lack of monitoring results in the operators not being aware of the situation of the water being supplied, and not knowing when there may be problems or shortcomings in the disinfection system.

5.9 The prime objective of disinfection is to kill harmful micro-organisms which could be present in water. Generally there is no monitoring for such micro-organisms (faecal coliforms) to determine if the disinfection process is effective or not.

6. RECOMMENDATIONS

6.1 From this study it is recommended that a brief handbook on disinfection for small schemes be compiled. The existing technical guide of the CSIR can be used as a basis for this, but the operator training and monitoring aspects should be added.

6.2 Secondly, it is recommended that some of the alternative disinfection technologies, particularly the on-site generation from salt of chlorine and/or mixed oxidants be evaluated in a selected few small schemes, and the operational parameters be established.

6.3 The information from this report, the handbook, and any further studies be distributed to relevant authorities.

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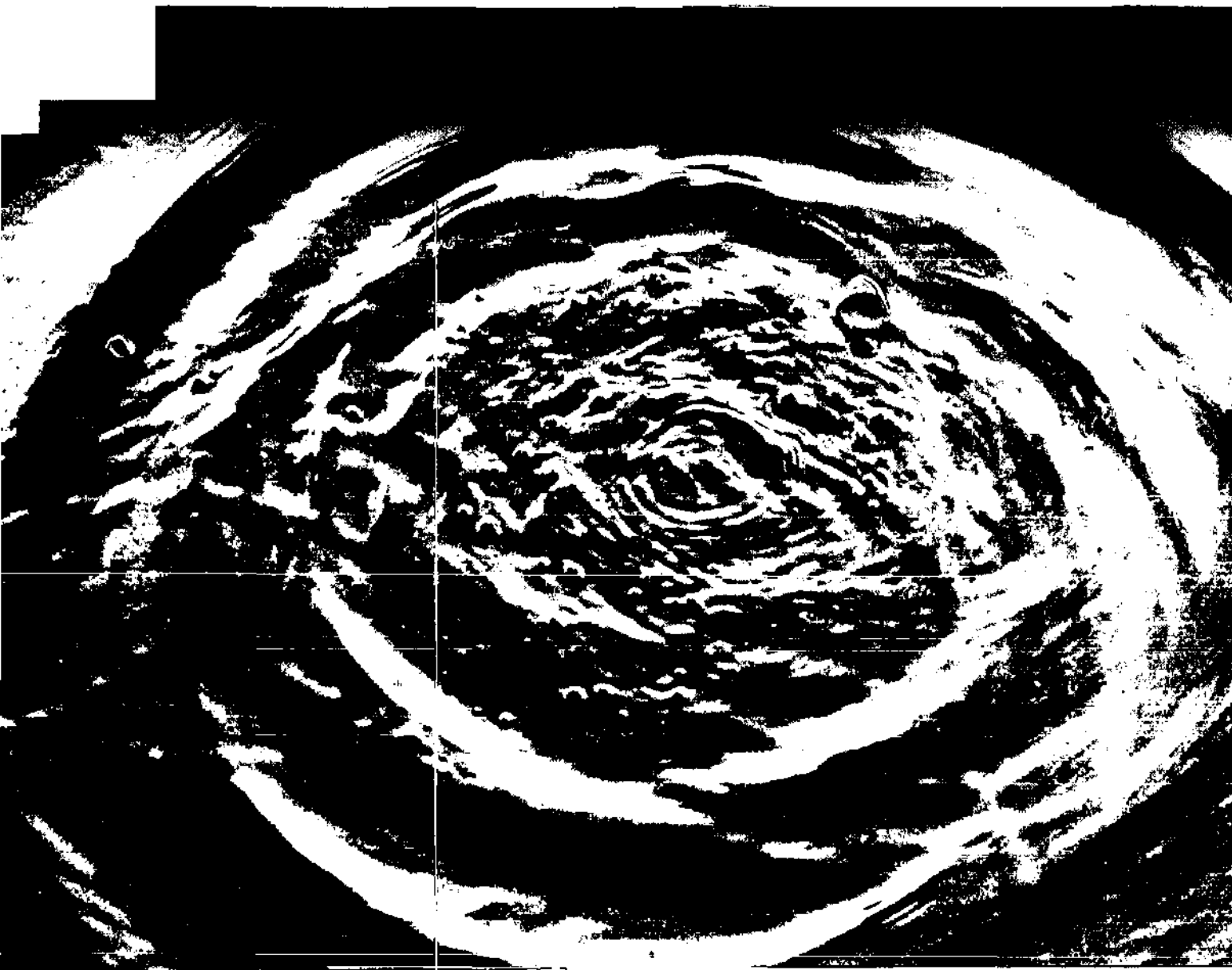

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