A FIRST ORDER INVENTORY OF WATER USE AND EFFLUENT PRODUCTION BY SA INDUSTRIAL, MINING AND ELECTRICITY GENERATION SECTORS

by

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Executive summary

The National Water Resources Strategy highlights the importance of both water availability and water quality for equitable and sustainable social and economic development. The WRC's Key Strategic Area for Water Use and Waste Management (KSA 3) is responsible for identifying and investing in research to address problems associated with all water use and waste production outside of agriculture and forestry.

The overall objective of this project was to compile a first order inventory of the amount of water used and effluent produced by the South African industrial, mining and power generation sectors, and to assess the impact these might have on water quality. The specific objectives were to:

1. Evaluate the status quo of data available on the quantity of water used and waste produced by the industrial, mining and power generation sectors, subdivided into useful sub-sectors and waste types.
2. Collect first order data for those sectors, sub-sectors and waste types for which sufficient data are available.
3. Categorise waste types according to their effect on water quality and synthesise the data to obtain an estimate of the threat that different sectors and sub-sectors pose to water quality.
4. Verify the findings of the study with practitioners in the field.
5. Produce a synthesis report on the current status of water use and waste production by the industrial, mining and power generation sectors with recommendations concerning those sectors and topics that require research investment.
6. Create an interactive database of water use and effluent production.

Research approach

The data obtained for this first order inventory originated from a number of different sources. The type of information received from the various sources differed, mainly due to limited monitoring and reluctance on behalf of both public and private organisations to make available sensitive information. Existing data sets were of limited value and outdated. It was therefore decided to identify the major water users in the country and target these organisations for information on water use and effluent production. This was done by obtaining water use information from metropolitan councils, and a number of DWAF regional offices. Using the metropolitan databases on water users, specific organisations were identified and additional information was requested on production processes, production figures, water use, effluent volumes and effluent quality.

The process was repeated for effluent production. The information was then grouped into sectors and the relative percentage per sector was determined for water use and then for effluent production. Data for effluent production was often not available and incomplete.

Results

From these data sets, a number of general trends in water use and effluent volume production were observed with respect to the industrial and food and beverage sectors.

Whenever there was a brewery within a metropolitan area, it was usually the major user of water. The brewery industry was also the major contributor to effluent produced in the metropolitan regions. Other important sectors in the metropolitan areas that produced large quantities of effluent were the pulp and paper industry and textile industries. The food and beverage industry as a whole was also a significant

producer of effluent in the sense that this industry was by far the most common industry present in all the metropolitan areas and it contributed significantly to the production of effluent.

When considering the total quantity of water used by these sectors, the industry sector consumed 55%, followed by mining (23%), power generation (20%) and the food industry (2%). The total effluent production followed a similar trend to usage, with the industry sector at 74%, mining at 10%, food and beverage at 9% and power generation at 7%. It is quite obvious that the industry sector accounted for more than 50% of the water used and more than 74% of the effluent produced. In terms of water use, the three leading industries were petroleum (42%), ferrous metals, i.e. metal plating (41%) and pulp and paper (14%). Regarding effluent production, pulp and paper took the lead at 57%, followed by the petroleum industry at 34%. These two industries accounted for more than 90% of the industrial effluent produced.

It is of great concern that many of the surveyed industries do not conduct any chemical analyses on the effluents that they produce and that where chemical analyses are done, they very seldom go beyond a few basic parameters like COD, phosphate and nitrate. The current data therefore merely indicates a trend rather than enabling the user of the data to determine the exact pollution load to the environment.

In terms of water risk analysis, the petroleum industry and the pulp and paper industry potentially poses the greatest risk in the industry sector and in fact overall taking all sectors into account. From the data, mining and power generation and the food and beverage sectors produce similar quantities of wastewater. In terms of risk, based on the chemical composition of the waste, the mining sector poses the greatest potential risk followed by the food and beverage sector and then power generation. The five most important food and beverage groups in terms of water use and effluent production were sugar (27%), poultry (24%), cold drink (17%), breweries (15%) and dairies (10%) in terms of water use, and in terms of effluent production, poultry (31%) followed by cold drinks (20%), breweries (18%), sugar (16%).

Discussion

The data obtained from the various metropolitan councils differed considerably with regard to level of detail. At present there is no system in place to regulate the level of detail that metropolitan councils should go to in obtaining information on effluent production (especially with regard to chemical composition) and as a result, the data obtained from the metropolitan councils was inconsistent and comparisons were not always possible. In many of the cases we suggest the extent to which chemical analyses are being done on the effluent be reconsidered so as to facilitate the process of fully appreciating the risks associated with it. Another aspect of the metropolitan data that may be improved upon is the mechanism for and extent to which existing information is made available to relevant authorities and concerned scientists. The database that was created contains valuable information and has been structured so that it can easily be updated. It incorporates facilities so that specific information types can easily be found and grouped together in accordance with the user's needs and then exported to spreadsheets for further processing.

In the determination of risk that the effluent may pose, a very important factor to be considered is whether the effluent is discharged into a municipal sewer system or whether the effluent is discharged directly into a natural watercourse without treatment. Most of the breweries are located within a metropolitan council and hence the effluent is discharged into a sewer so that it poses minimal risk to the environment. Similarly, for the dairy industry and the pulp and paper industry, where many of the facilities are located within a metropolitan council, the risk is limited due to effluent discharge into a sewer. However, in some cases pulp and paper plants are not located inside of a metropolitan council and in such cases they pose a major threat to the environment, if the effluent is not treated before being discharged. This also holds true for the tannery industry and any other industries located outside of a metropolitan area.

It is also disappointing to have received so little recent data from the South African mining industry in terms of the volumes of effluent produced. The study team did however consider reports of earlier studies and reported the earlier information where appropriate. From previous studies it was clear that the mining industry is a major user of water and also produces significant quantities of effluent that may have a negative impact on the environment.

Although the electricity generation sector can be considered a major water user in South Africa (accounting for 2% of the total water demand in the country according to the NWRS), the effluent resulting from this sector is minimal, as most of the water evaporates in the coal fired process.

The biggest limitation experienced in the execution of the project was that the project team had to rely on the co-operation of numerous institutions (national government, local authorities, and private sector companies). Some organisations showed interest in the project, were transparent about the information they had and cooperated with our project team, Unfortunately, it was also our experience that many institutions were reluctant to provide us with the necessary information, mainly because of concerns regarding confidentiality of data, fear of prosecution and concerns that transparency regarding effluent production could lead to them being forced to incur additional treatment costs.

Recommendations

As there are currently no standard requirements in place for municipal councils with regard to effluent monitoring, it is recommended that such a standard be developed and implemented in order to obtain more accurate information on the chemical composition of the effluent.

It is recommended that initiatives be undertaken to improve the data available for these industries and that the database developed as part of this study, be updated accordingly. The availability of data relating to the mining sector in general, especially with regard to effluent production and quality, proved to be an issue of concern. The mining sector is a major water user as well as a major contributor to effluent in South Africa. The fact that much of the effluent resulting from mining activities is often not sent to sewerage plants, but is managed (with differing degrees of success or failure) on site increases the risk posed. Therefore, we recommend that a study, focussing specifically on the mining sector, be undertaken in order to collect up-to-date, comprehensive and reliable data so that accurate risk assessments and more relevant recommendations can be made.

Conclusions

The incomplete data on effluent production highlights a problem that we face in South Africa in terms of understanding the exact load of waste that is associated with industry. This is of great concern when it comes to managing the impact of effluent production on the environment.

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ABBREVIATIONS

AMD	Acid mine drainage
AOX	Absorbable organically bound halogens
$BOD_{(5)}$	Biological oxygen demand
COD	Chemical oxygen demand
CPMFI	Cleaner Production in the Metal Finishing Industry Project
CSIR	Council for Scientific and Industrial Research
DO	Dissolved oxygen
DOT	Department of Transportation
DWAF	Department of Water Affairs and Forestry (South Africa)
EC	Electric conductivity
EEVTEQ	Estimated Toxic Exposure Values based on nonylphenol toxic equivalency quotients
FFO	Fresh Fish Operations
GDP	Gross Domestic Product
hℓ	Hecto litre (100 litres)
ISP	Internal Strategic Perspectives
kℓ	Kilo litre (1 000 litres)
Mℓ	Mega litre (1 000 000 litres)
NPE	nonylphenol ethoxylates
NWRS	National Water Resources Strategy
PGM	Platinum group metals
ppm	Parts per million
RMAA	Red Meat Abattoir Association
ROM	Run of mine
RWD	Raw water discharge
SIC	Standard Industrial Classification
SRB	Sulphate reducing bacteria
SS	Suspended Solids
TDS	Total Dissolved Solids
TKN	Total Kjedahl nitrogen
TME	Textile mill effluents
TSS	Total suspended solids
VRSAU	Vaal River Systems Analysis Update
VSS	Volatile suspended solids
WMA	Water Management Area
WRC	Water Research Commission
WSAM	Water Situation Assessment Model
WWTP	Waste Water Treatment Plant

1 INTRODUCTION

The National Water Resources Strategy highlights the importance of both water availability and water quality for equitable and sustainable social and economic development. It is recognised that South Africa, being an arid country, needs to take considerable care when dealing with the regulation of the available resource. The WRC recognises this need and its aim for this project, was to determine the influence that industry, mining and the power generating industry has on South African water resources in terms of water use, effluent volume and effluent quality. This project identified industries, which should be targeted in future research initiatives in order to improve current practices with respect to water use and effluent production.

The data obtained for this first order inventory originated from a number of different sources. The type of information received from the various sources differed, mainly due to limited monitoring and reluctance on behalf of both public and private organisations to make available sensitive information. Existing data sets were of limited value and outdated. It was therefore decided to identify the major water users in the country and target these organisations for information on water use and effluent production. This was done by obtaining water use information from metropolitan councils, and a number of DWAF regional offices. Using the metropolitan databases on water users, specific organisations were identified and additional information was requested on production processes, production figures, water use, effluent volumes and effluent quality.

The process was repeated for effluent production. The information was then grouped into sectors and the relative percentage per sector was determined for water use and then for effluent production. The data we received was taken and used directly from the records of the metropolitan areas. Data for effluent production was often not available and incomplete.

The National Water Resource Strategy (NWRS) (DWAF, 2004) provides an indication of water use requirements for major activities, including those not in this study, e.g. agriculture. Further, some activities such as mining and other bulk water users, and industrial use within municipal boundaries are not segregated in the NWRS, which limits the extent of the applicability of this information to the specific industrial sectors considered in this WRC study. However, this information is still useful for this project as it provides some background information on a national scale. As a result, although this information is deemed helpful and informative, caution should be taken where this information is to be interpreted in collaboration with data sets obtained from smaller geographical units (e.g. metropolitan councils and individual companies) than the Water Management Areas (WMAs) used in the NWRS.

Subsequently we give a summarised version of the information given in the NWRS, which is deemed most relevant to this first order inventory and which serves to provide the bigger picture as background against which the information in this report should be interpreted.

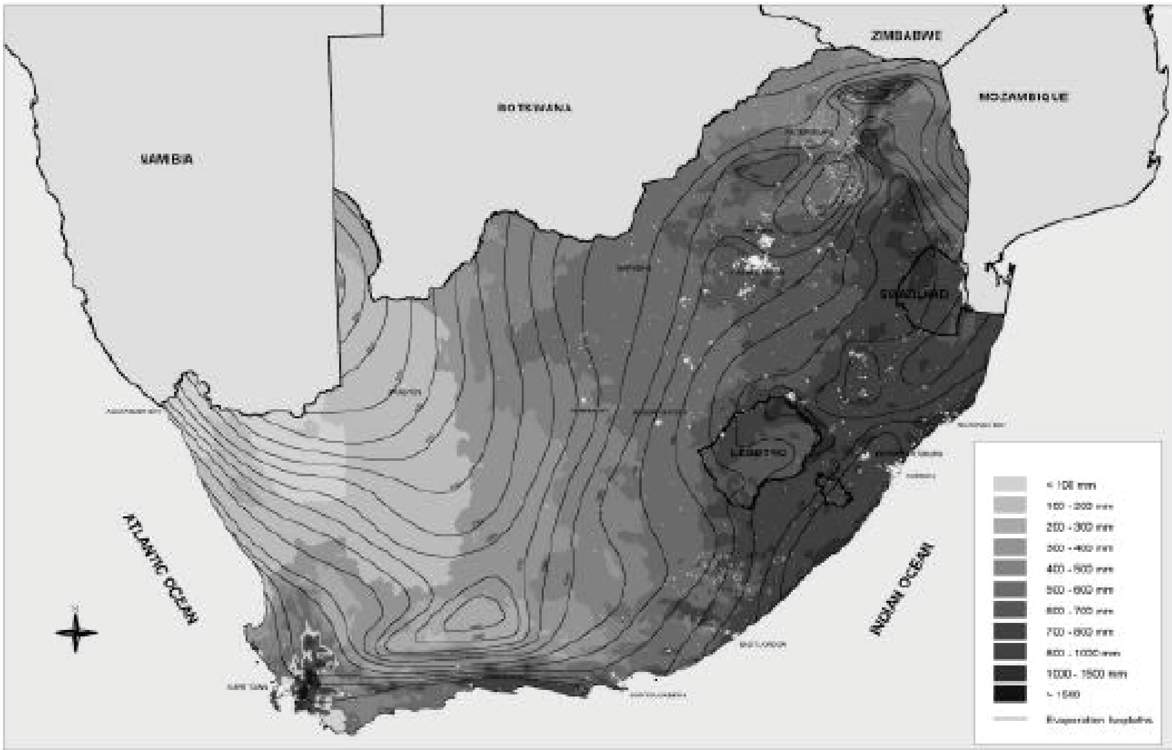
The four main purposes of the National Water Resource Strategy are to

1. Act as the national framework for managing water resources
2. Act as the framework for the preparation of catchment management strategies
3. Provide water-related information
4. Identify development opportunities and constraints.

Much of the information provided in the NWRS is deemed relevant to this study. For example, in Chapter 2 the document provides aggregated estimates of the present availability of and requirements for water in each of the WMAs. It also indicates how water availability and water requirements may be expected to change in the future, and describes possible strategies and interventions for achieving a balance between water availability and requirements. A summary of the relevant information is given below.

With an average rainfall of about 450 mm/a, well below the world average of about 860 mm/a, evaporation comparatively high (**Figure 1-1)** and the combined flow of all the rivers in the country amounting to approximately 49 000 106 m^3/a, less than half of that of the Zambezi River, South Africa's water resources are, in global terms, scarce and extremely limited. To aggravate the situation, most urban and industrial development, as well as some dense rural settlements, have been established in locations remote from large watercourses. As a result, the requirement for water in many river basins far exceeds its natural availability.

Figure 1-1: SA rainfall and evaporation



In order to facilitate the management of water resources, the country has been divided into 19 catchment-based WMAs. The location and boundaries of the different water management areas, as well as inter-water management area transfers, are shown in **Figure 1-2**. Key statistics for each water management area follow in **Figure 1-3**. The information given here is intended to identify areas where there are imbalances in availability and requirements, and to serve as background for the formulation of more detailed, nationally-consistent strategies to reconcile the water requirements and availability in each WMA. The data is not sufficiently accurate to consider the water balance in smaller geographic areas, or to address the water requirements of individual user sectors in these areas.

Figure 1-3 clearly demonstrates the exceedingly varied conditions between the WMAs. The Crocodile West and Marico WMA for example, where the largest proportional contribution to GDP is produced, is one of the WMAs with the smallest mean annual runoff. In contrast, economic activity in the Mzimvubu to Keiskamma WMA is relatively low despite it being the WMA with the highest mean annual runoff in the country.

The available yield for the different WMAs in the year 2000, is given in **Table 1-1**, while the reconciliation of the requirements and availability of water in each WMA is provided in **Table 1-2**. A more detailed specification of the water requirements by different water use sectors in each WMA is given in **Table 1-3**. Sectoral contributions to the Gross Domestic Product as based on 1997 figures are given graphically in **Figure 1-4**.

Figure 1-2: Location of water management areas and inter water management area transfers

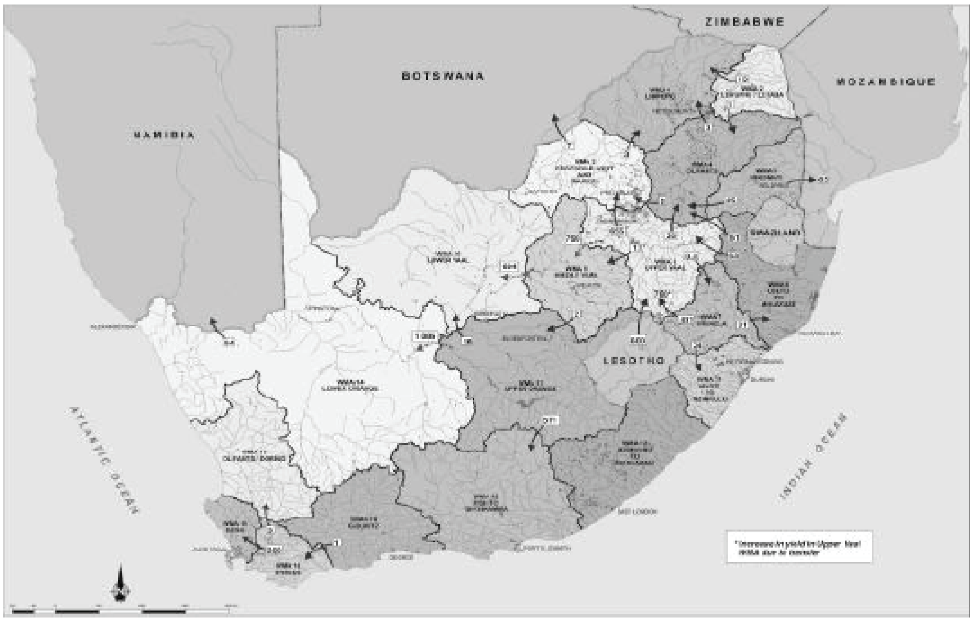


Figure 1-3: Comparison of the mean annual runoff (MAR), population and economic activity (GDP) per water management area

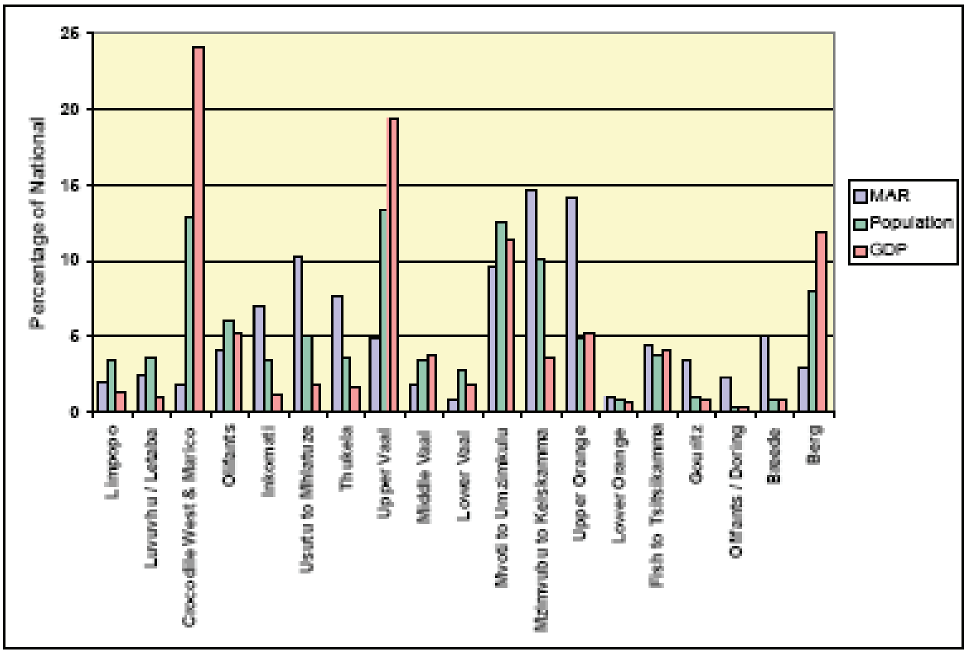


Table 1-1: Available yield in year 2000 (10^6 m^3)

WMA	Natural Resource		Usable return flow			Total yield
	Surface Water (2)	Ground Water (3)	Irrigation	Urban	Mining and bulk Industrial	
1 Limpopo	160	98	8	15	0	281
2 Luvuvhu/Letaba	244	43	19	4	0	310
3 Crocodile West & Marico	203	146	44	282	41	716
4 Olifants	410	99	44	42	14	609
5 Inkomati	816	9	53	8	11	897
6 Usutu to Mhlatuze	1019	39	42	9	1	1 110
7 Thukela	666	15	23	24	9	737
8 Upper Vaal	598	32	11	343	146	1 130
9 Middle Vaal	(67)	54	16	29	18	50
10 Lower Vaal (3)	(54)	126	52	0	2	126
11 Mvoti to Umzimkulu	433	6	1	57	6	523
12 Mzimbuvu to Keiskamma	777	21	17	39	0	854
13 Upper Orange	4 311	65	34	37	0	4 447
14 Lower Orange (4)	(1 083)	4	96	1	0	(962)
15 Fish to Tsitsikamma	260	36	103	19	0	418
16 Gouritz	191	64	8	6	6	275
17 Olifants/Doring	266	45	22	2	0	335
18 Breede	687	109	54	16	0	866
19 Berg	403	57	11	37	0	505
TOTAL for country	10 240	1 088	876	870	254	13 227

(1) Transfers into and out of water management areas are not included above, but are covered in Table 1.2.

(2) Yield from run-of-river and existing storage, after allowance for the impacts on yield of the ecological component of the Reserve, river losses, alien vegetation, rain-fed sugar cane and urban runoff.

(3) Estimated use from existing boreholes and springs. As a result of development of groundwater for irrigation since the compilation of the database for the NWRS, total groundwater use may exceed this estimate. The increase is mainly due to growth in irrigation water requirements, and therefore does not significantly impact on the overall water balances given in the NWRS.

(4) Negative figures under surface water caused by river losses being larger than the incremental runoff from within the WMA.

Table 1-2: Reconciliation of the requirements and availability of water for year 2000 (10^6 m^3)

WMA	Reliable local yield	Transfers in (3)	Local requirements	Transfers out (3)	Balance (1, 2)
1 Limpopo	281	18	322	0	(23)
2 Luvuvhu/Letaba	310	0	333	13	(36)
3 Crocodile West & Marico	716	519	1 184	10	41
4 Olifants	609	172	967	8	(194)
5 Inkomati	897	0	844	311	(258)
6 Usutu to Mhlatuze	1 110	40	717	114	319
7 Thukela	737	0	334	506	(103)
8 Upper Vaal	1 130	1 311	1 045	1 379	17
9 Middle Vaal	50	829	369	502	8
10 Lower Vaal (3)	126	548	643	0	31
11 Mvoti to Umzimkulu	523	34	798	0	(241)
12 Mzimbuvu to Keiskamma	854	0	374	0	480
13 Upper Orange	4 447	2	968	3 149	332
14 Lower Orange (4)	(962)	2 035	1 028	54	(9)
15 Fish to Tsitsikamma	418	575	898	0	95
16 Gouritz	275	0	337	1	(63)
17 Olifants/Doring	335	3	373	0	(35)
18 Breede	866	1	633	196	38
19 Berg	505	194	704	0	(5)
TOTAL for country	13 227	0	12 871	170	186

(1) Brackets around numbers indicate a negative balance.

(2) Surpluses in the Vaal and Orange WMAs are shown in the most upstream water management area where they become available (that is, the Upper Vaal and Upper Orange WMAs)

(3) Transfers into and out of water management areas may include transfers between WMAs as well as to or from neighbouring countries. Yields transferred from one WMA to another may also not be numerically the same in the source and recipient WMA. For this reason, the addition of transfers into and out of WMAs does not necessarily correspond to the country total. The transfer of water from Lesotho to South Africa is reflected in the table as being from the Upper Orange WMA.

Table 1-3: Water requirements for year 2000 (10^6 m^3/a)

WMA	Irrigation	Urban (1)	Rural (1)	Mining and bulk industrial (2)	Power generation (3)	Afforestation (4)	Total local requirements
1 Limpopo	238	34	28	14	7	1	322
2 Luvuvhu/Letaba	248	10	31	1	0	43	333
3 Crocodile West & Marico	445	547	37	127	28	0	1 184
4 Olifants	557	88	44	94	181	3	967
5 Inkomati	593	63	26	24	0	138	844
6 Usutu to Mhlatuze	432	50	40	91	0	104	717
7 Thukela	204	52	31	46	1	0	334
8 Upper Vaal	114	635	43	173	80	0	1 045
9 Middle Vaal	159	93	32	85	0	0	369
10 Lower Vaal (3)	525	68	44	6	0	0	643
11 Mvoti to Umzimkulu	207	408	44	74	0	65	798
12. Mzimvubu to Keiskamma	190	99	39	0	0	46	374
13 Upper Orange	780	126	60	2	0	0	968
14 Lower Orange (4)	977	25	17	9	0	0	1 028
15 Fish to Tsitsikamma	763	112	16	0	0	7	898
16 Gouritz	254	52	11	6	0	14	337
17 Olifants/Doring	356	7	6	3	0	1	373
18 Breede	577	39	11	0	0	6	633
19 Berg	301	389	14	0	0	0	704
TOTAL for country	7 920 62%	2 897 23%	574 4%	755 6%	297 2%	428 3%	12 871

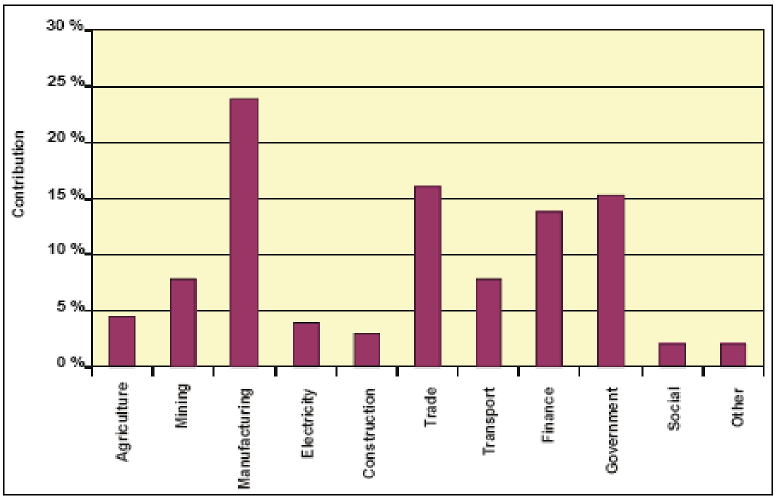
(1) Includes the component of the Reserve for basic human needs at 25 litres/person/day.

(2) Mining and bulk industrial that are not part of urban systems

(3) Includes water for thermal power generation only, since water for hydropower, which represents a small portion of power generation in South Africa, is generally also available for other uses. (For ease of direct comparison with Eskom these numbers have not been adjusted for assurance of supply; the quantitative impact of which is not large).

(4) Quantities given refer to impact on yield only. The incremental water use in excess of that of natural vegetation is estimated at 1 460 10^6 m^3/a.

Figure 1-4: Sectoral contributions to GDP (1997)



Water quality refers to the physical, chemical and biological characteristics of water. It describes how suitable the water is for its intended purpose in nature or for use by different water users. Different ecosystems and different user groups can have widely variable water quality requirements.

The factors influencing water quality can either be natural or result from human activity. The main natural factor that influences the quality of water is the geology of the formations over which water flows or through which it percolates, which gives rise to sediment load and mineralization of the water. Vegetation, the slope of the land and flow rate may also influence water quality. The impacts of human activity on water quality are more varied and complex. Diffuse pollution results from various land use activities, most significantly agricultural practices and human settlements as well as the precipitation of pollutants from the air. Point sources of pollution typically are where urban, industrial and mining effluent is discharged to streams and other receiving waters. Water resource management interventions such as diversion, storage and inter-catchment transfer of water also impact on water quality.

Physical characteristics (mainly temperature, sediment load and turbidity) impact on aquatic life, recreational uses and the treatment of water for other uses. The main impacts of chemicals in the water relate to salination (dissolved salts), which may render water unfit or very costly to treat for application to many uses such as irrigation and household use. Eutrophication, which is the enrichment of water with plant nutrients, gives rise to excessive growth of macrophytes and microscopic plants such as algae and cyanobacteria in rivers and reservoirs. Cyanobacteria (often referred to as blue-green algae) are toxic, and may cause the water to be unfit for recreational, irrigation and domestic use.

Pollution by metals and manufactured organic components such as herbicides and pesticides is also becoming an increasing problem in South Africa due to industrialisation, and can have serious impacts on human and animal health. Microbial contamination, arising mainly from untreated sewage entering water resources due to poorly maintained or a lack of sanitation services, poses a widespread problem in South Africa, carrying pathogens that may cause water borne diseases such as diarrhoea and cholera.

The main activities that can contribute to the deterioration of water quality are mining (acidity and increased metals content), urban development (salinity, nutrients, microbiological), industries (chemicals, toxins), and agriculture (sediment, nutrients, agro-chemicals, salinity through irrigation return flows). A general perspective on the WMAs in which physico-chemical water quality characteristics may be outside the ideal ranges is given in the table below.

Table 1-4: Water quality characteristics associated with WMAs

	WMA	Domestic use								Irrigation use				Recreational use
		F	TDS	Ca	Mg	SO_4	Cl	Na	K	SAR	EC	pH	Cl	
1	Limpopo													
2	Luvuvhu/Letaba											(+)		
3	Crocodile West & Marico											(+)		X
4	Olifants	X									L	(+)		X
5	Inkomati													
6	Usutu to Mhlathuze						X				L	(+)	L	
7	Thukela													X
8	Upper Vaal					X								X
9	Middle Vaal													X
10	Lower Vaal													X
11	Mvoti to Umzimkulu													X
12	Mzimbuvu to Keiskamma											(+)		X
13	Upper Orange		X					X				(+)		
14	Lower Orange		X					X		L	M	(+)	M	X
15	Fish to Tsitsikamma		X	X		X	X	X		L	LMH	(-) (+)	LMH	X
16	Gouritz		X	X	X	X	X	X	X	LM	H	(-)	H	
17	Olifants/Doring													
18	Breede						X				L		L	X
19	Berg													

KEY

<u>Domestic use</u>: X indicates that the water quality indicator is outside the ideal range for domestic use at some locations in the WMA

F = Fluoride; TDS = Total dissolved salts; Ca = Calcium; Mg = Magnesium; SO_4 = Sulphate; Cl = Chloride; Na = Sodium; K = Potassium

<u>Irrigation use</u>: A symbol indicates that water quality indicator is outside the target water quality range for irrigation use at some locations in the WMA, where L, M and H means Low, Medium or High risk, (+) = alkaline and (-) = acidic.

SAR = Sodium Absorption Rate; EC = Electrical Conductivity; pH = a measure of acidity/alkalinity; Cl = Chloride

<u>Recreational use</u>: X indicates that the water quality indicator is occasionally outside the acceptable levels for recreational use at some locations because toxic cyanobacteria have been found.

The NWRS further stresses the need for chemical, biological and physical characteristics of water to be addressed when water resource management options and other interventions are being considered.

Waste is defined in the National Water Act and the Environment Conservation Act. These definitions are given below.

- Definition of waste in terms of the National Water Act, 1998 (Act 36 of 1998): "Waste" includes any solid material or material that is suspended, dissolved or transported in water (including sediment) and which is spilled or deposited on land or into water resource in such volume, composition or manner as to cause, or to be reasonably likely to cause, the water source to be polluted.

- Definition of waste in terms of the Environment Conservation Act, 1989 (Act 73 of 1989): “Waste” means any matter, whether gaseous, liquid or solid or any combination thereof, which is from time to time designated by the Minister by notice in the Gazette as any undesirable or superfluous by-product, emission, residue or remainder of any process or activity.

The definition of the National Water Act (1998) was used during this study.

2 METHODOLOGY

The WRC's Key Strategic Area for Water Use and Waste Management (KSA 3) is responsible for identifying and investing in research to address problems associated with all water use and waste production outside of agriculture and forestry. In order to identify and prioritise those facets that need most urgent attention, it is important to quantify the water use and waste production by different sectors. Without such information it is, for instance, difficult to know whether the present investment in research in this KSA and more specifically the Thrust on Industrial and Mine-water Management, has the right mix. Such information is also necessary to provide strategic direction to research initiatives and to ensure that all important research areas are receiving the required attention.

The overall objective of this project was to compile a first order inventory of the amount of water used and waste produced by the South African industrial, mining and power generation sectors, and to assess the impact these might have on water quality. The specific objectives were to:

1. Evaluate the status quo of data available on the quantity of water used and waste produced by the industrial, mining and power generation sectors, subdivided into sub-sectors and waste types (Addressed in Chapter 3).
2. Collect first order data for those sectors, sub-sectors and waste types for which sufficient data are available (Addressed in Chapter 4 and 5).
3. Categorise waste types according to their effect on water quality and synthesise the data to obtain an estimate of the threat that different sectors and sub-sectors pose to water quality (Addressed in Chapter 6).
4. Verify the findings of the study with practitioners in the field (Addressed in Chapter 6).
5. Produce a report on the current status of water use and waste production by the industrial, mining and power generation sectors with recommendations concerning those sectors and topics that require research investment (Addressed in Chapter 10).
6. Create a database of water use and effluent production. This database contains valuable information and has been structured so that it can easily be updated. It incorporates facilities so that specific information types can easily be found and grouped together in accordance with the user's needs and then exported to spreadsheets for further processing.

The methodology followed to address these aims, are presented in the following paragraphs.

2.1 EXISTING DATABASES ANALYSIS

A number of databases were investigated to assess the currently available information. Usable information was identified where possible. Shortcomings in these databases were also identified. Additional water use and effluent data was obtained from municipal and metropolitan councils. This information was used to identify organisations from which more detailed data was obtained.

This section of the project dealt with:

1. Obtaining, reviewing and extracting relevant existing information on water use and waste production by the industrial, mining and power generation sectors. Examples of the existing databases used are:

   - NWRS (National Water Resources strategy)
   - WSAM (Water Situation Assessment Model)
   - Previous catchment studies
   - ISP (Internal Strategic Perspectives) studies
   - VRSAU (Vaal River System Analysis Update study)
   - Various studies undertaken by WRC, DWAF and Eskom
   - DWAF's register of water users
   - Arcus Gibb project data for waste and other studies
   - Arcus Gibb project data for the National Chemical Profile Study

2. Analysis of existing data for inconsistencies, missing information and the relative significance of different sub-sectors and waste types. This was done in collaboration with the reference group and other experts in the fields of water use and waste.

3. A workshop was held to review the data and to discuss methods to improve the data. The outcome of the workshop was a verification of the data collected and guidance on gaps in the data providing a workable solution to improve the data through first order data collection.

2.2 METROPOLITAN INFORMATION

In order to improve on the existing data sets, it was decided to identify the major water users in the country and target these organisations for information on water use and effluent production. This was done by obtaining water use information from metropolitan councils, and a number of DWAF regional offices.

Although the format and the type of information received differed considerably, this information was used as a starting point for the second phase of data collection. Major water users and/or producers of effluent were identified and contacted in order to obtain more detailed information on water use and waste production for specific sectors.

2.3 SECTORAL INFORMATION

Using the metropolitan databases on water users, specific organisations were identified and additional information was requested on production processes, production figures, water use, effluent volumes and effluent quality. Not all of the organisations contacted were helpful in providing this information – their main concern being confidentiality. The internet was also used as a source of information regarding production processes and general practices.

Data were collected by means of questionnaires, telephonic discussions and meetings with practitioners in the field.

After completion of the data collection phase, the data was used to estimate the threat that different sectors and sub-sectors pose to water quality, based on a categorisation of the effluent, volume, effluent composition and the potential effect on water quality.

2.4 THREAT ESTIMATION

The information gathered for each sector was analysed and assessed with regard to the environmental threat posed by the effluent resulting from the specific process.

The interim threat estimates of the different sectors and sub-sectors were circulated to prominent stakeholders and practitioners in the field for comment and verification. As part of this verification process a second workshop was held with the reference group, project team and stakeholders.

A database of all data collected on water use and effluent production was synthesized to indicate and analyse the current status of water use and waste production and the impact that this might have on the receiving water.

Sectors that potentially posed the highest risk were identified and recommendations were made to future focus areas for research.

2.5 DEVELOPMENT OF A DATABASE

The data obtained for this first order inventory originated from a number of different sources. The type of information received from the various sources also differed, mainly due to limited monitoring and reluctance on behalf of both public and private organisations to make available sensitive information. As a result, normalisation and sifting was done so that the data could be archived in a way that enables comparison of the different data sets.

3 A REVIEW OF EXISTING DATABASES

Existing databases on water use and effluent waste production by the industrial, mining and power generation sectors was obtained and reviewed. These results will now be discussed in detail.

3.1 ARCUS GIBB PROJECT DATA ON WATER QUALITY

ARCUS GIBB projects on water quality were reviewed and data included where applicable. The data was unfortunately mostly confidential and either broad based or too focussed. Certain relevant organisations were approached to ascertain whether their information could be included as representative samples of particular water use sectors and results were included in this study. Confidentiality was respected and details of the organisations and location were not published.

3.2 ARCUS GIBB PROJECT DATA FOR THE NATIONAL CHEMICAL PROFILE STUDY

The ARCUS GIBB National Chemical Profile study identified SIC codes, which are also used in the Statistics South Africa database. These SIC codes were used to identify the different sectors in this study.

3.3 BASIN STUDIES (FOR VARIOUS MAJOR CATCHMENTS)

The water quality component of most major catchment studies was performed using hydro-salinity models that were calibrated against observed water quality data for surface and groundwater. This implies that the data obtained for these studies do not differentiate between effluent quality resulting from isolated sectors, but rather takes into account the combined effect of all return flows present in that particular catchment. As a result, this data, although some of it quite recent, was deemed unsuitable for this study.

3.4 DWAF'S REGISTER OF WATER USERS

DWAF keeps records of effluent quality returned to resource by means of the Water management system (WMS).

Before a user is entered into the system, it is first determined whether the user discharges into the resource or whether it discharges its effluent to sewage works. If the latter is applicable, the user is not entered into the system as an isolated entity, but rather the combined effluent return flow quality of all industries discharging to a particular sewage plant is entered into the system. Since the majority of industries discharge to sewage plants, the information on specific industrial sectors in the WMS system is very limited.

A vast amount of relevant information is contained in the reports of water management plans submitted to DWAF by industries and mines. These reports were not available for consideration in this study.

3.5 INTEGRATED STRATEGIC PERSPECTIVE STUDIES CURRENTLY BEING UNDERTAKEN BY DWAF FOR ALL CATCHMENT MANAGEMENT AREAS (CMAs)

Although mention is made of some of the major economic activities in each of the CMAs, specific and recent data on wastewater quality was not available. The problems are similar to those for basin studies mentioned above.

3.6 NATIONAL CHEMICAL MONITORING PROGRAMME

The National Chemical Monitoring Programme is a Department of Water Affairs and Forestry (DWAF)-owned network of water quality monitoring points, which have been in operation since the early 1970s. Samples are regularly collected at approximately 1 600 monitoring stations at a frequency that varies from weekly to monthly sampling. The samples collected for this programme are analysed at the laboratories of the Directorate for Resource Quality Services and the data is stored on DWAF's database and information management system, namely the Water Management System (WMS). Data obtained through this network has been used in the National Water Resource Quality Status Report: Inorganic Chemical Water Quality of Surface Water Resources – The Big Picture. This data is freely available from the DWAF website in graphical form and relatively up to date.

However, this data only reports on the water quality of points in the river and only with respect to a selection of inorganic quality parameters. Consequently this database was not of much use for this study, which aimed to focus on specific industrial, mining and power generation sub-sectors.

3.7 NATIONAL WATER RESOURCE STRATEGY (NWRS)

The NWRS (DWAF, 2004) provides an indication of water use requirements for major activities, including those not discussed in this study, e.g. agriculture. Further, some activities such as mining and other bulk water users are combined in the NWRS, which limits the applicability of this information to the specific industrial sectors considered in this study. This information was nevertheless useful since it provided some background information on a national scale.

3.8 NATSURV INVESTIGATION

The NASURV study was useful in terms of identifying industrial sectors. The water use data was however outdated, dating back to the 1980s.

3.9 VAAL RIVER SYSTEMS ANALYSIS UPDATE STUDY

This study was one of the basin studies taken into consideration. The same comments were valid as discussed in section 3.3 above.

3.10 MISCELLANEOUS STUDIES UNDERTAKEN BY STATISTICS SOUTH AFRICA, DWAF AND THE WRC

3.10.1 Statistics South Africa

Statistics concerning various industrial activities in South Africa are gathered by Statistics South Africa and Customs and Excise. Statistics South Africa use Standard Industrial Classification (SIC) codes and an Industry Code for classification of all economic activities in South Africa.

3.10.2 DWAF

Refer to paragraphs 3.3, 3.5 and 3.7 above.

3.10.3 WRC

A WRC report titled “Water and wastewater management in the power generating industry” (WRC Project No K5/1390) on the effluent produced by Eskom" was obtained. This was a recent study and the information included in the report provided information for the power generation sector.

3.11 WATER LICENCES ISSUED BY DWAF.

WARMS is an information system that is updated by the DWAF regional offices and was designed to manage information on registered water users. The system has the capacity to store information per registered user on effluent volumes and chemical composition (based on a number of samples). This database is still being populated and the information currently available on the system did not provide information relevant to this study.

3.12 WATER SITUATION ASSESSMENT MODEL (WSAM)

The WSAM water quality model is used to perform a mass balance of the total salt load of the water resources within a catchment. This model is used to calculate the TDS (total dissolved salts) concentration of supply to different water use sectors (rural, urban, mining etc) and uses factors, which can be calibrated to estimate the return flow quality from these sectors. Although the default values were obtained from literature reviews, the WSAM values were not used in this study due to the following reasons:

1. No distinction was made between different kinds of mining effluent
2. Industrial effluent was not sub-divided into specific industrial activities
3. Effluent generally entered the system after purification

Nevertheless, the WSAM model computes available resources on a quaternary catchment level based on various water use sectors, including domestic, bulk mining, agricultural and forestry.

3.13 METROPOLITAN DATA COLLECTION

In order to improve on the existing data sets, it was decided to identify the major water users in the country and target these organisations for information on water use and effluent production. This was done by obtaining water use information from metropolitan councils, and a number of DWAF regional offices.

4 WATER USE AND EFFLUENT/PRODUCTION FOR REGIONAL METROPOLITAN AREAS

4.1 INTRODUCTION

An important part of data collection involved identifying a reliable source of information. It was argued that metropolitan councils would be such a source of information, since they bill their customers based on water usage. All the major metropolitan councils where hence approached to provide such data.

The data for all the metropolitan areas from which data was received was ranked to identify the top 80% of the industrial water users. The data was taken and used directly from the records of the major metropolitan councils. The process was repeated for effluent production. The information was then grouped into sectors and the relative percentage per sector on a national basis was determined for water use and then for effluent production. Effluent production seldom correlated with water use data. The main reason for this was the lack of information on effluent production in many of the metropolitan areas. The determination of the water use data was a much easier task since the figures were derived from billing. The effluent data was less accurate and the discussion of the results therefore points out trends rather than accurate information. The trends were nevertheless important, since they pointed out who the major effluent producers were.

The incomplete data on effluent production highlights the problems that South Africa faces in terms of understanding the exact load of waste that is associated with industry. This is of great concern when it comes to managing the impact of effluent production on the environment. This indicates a serious gap in the monitoring and management of the risks associated with effluent production. The results for each metropolitan area are discussed in more detail below.

4.2 AMATHOLE METROPOLITAN COUNCIL (East London)

In the East London area 43% of the water was used by the automotive industry, followed by the food industry (36%) and the textile industry (9%) (**Figure 4-1**). The effluent production followed the trends for water use with (44%) of the water use by the motor industry followed by the food sector (41%) and the textile industry (15%) (**Figure 4-2**).

Figure 4-1: Top 80% of water users in the Amathole Metropolitan region

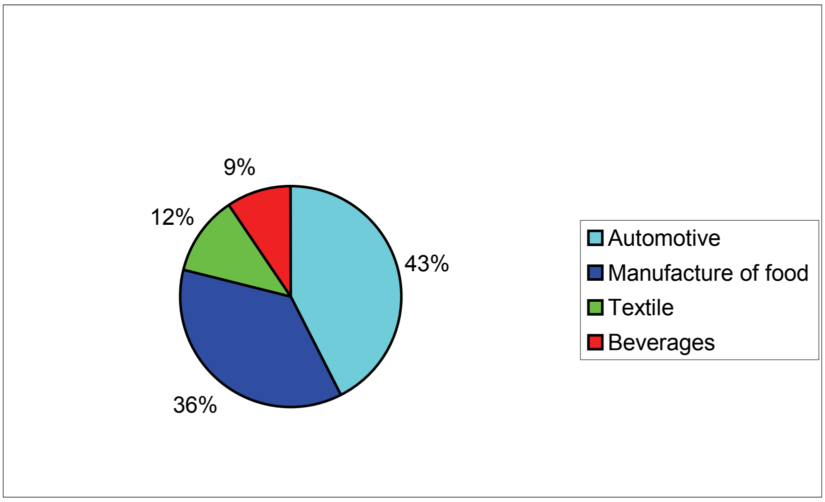
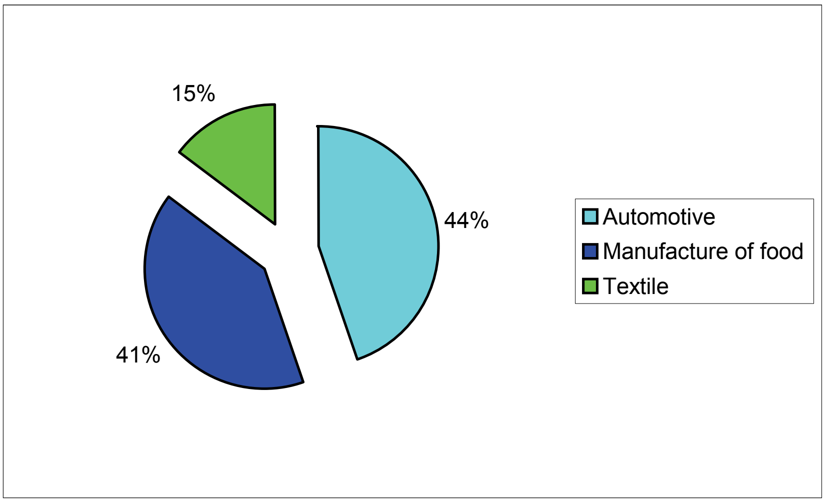


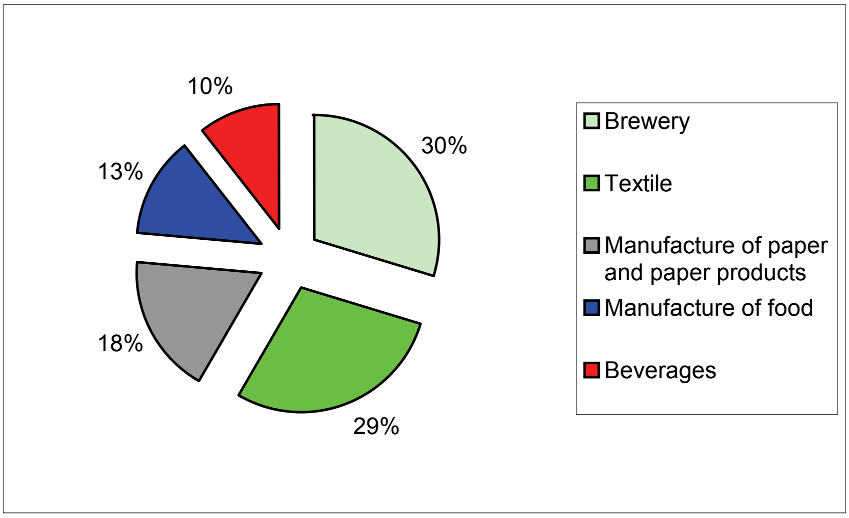
Figure 4-2: Top 80% of effluent producers in the Amathole Metropolitan region



4.3 THE CITY OF CAPE TOWN

In the Cape Town metropolitan area breweries produced 30% of the total effluent, followed by the textile industry (29%) paper and paper products (18%) food manufacturing (13%) and beverages (10%) (**Figure 4-3**). Unfortunately the metropolitan council supplied no information related to water use per sector.

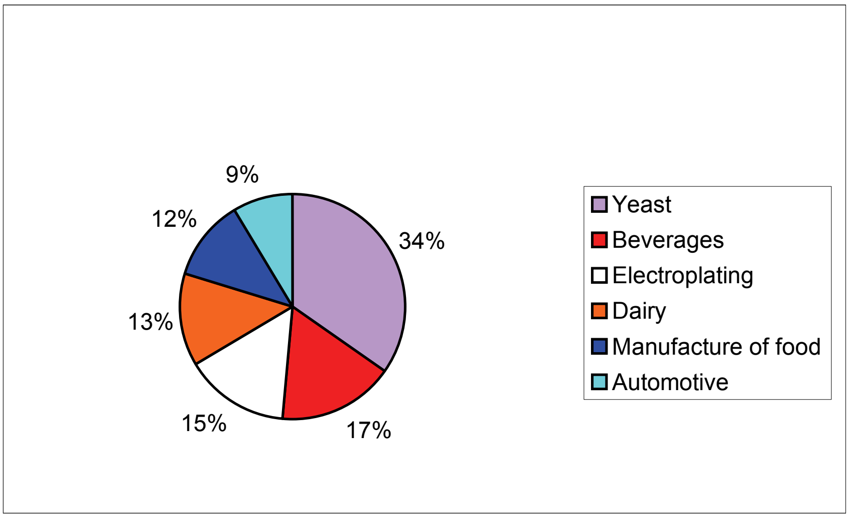
Figure 4-3: Top 80% of effluent producers in the City of Cape Town Metropolitan region



4.4 CITY OF JOHANNESBURG METROPOLITAN COUNCIL

For the Johannesburg area only water use data was available. From the water use data one could predict that the yeast industry produced most of the effluent followed by beverages, electroplating, dairy, food manufacturing and the automotive industry (**Figure 4-4**).

Figure 4-4: Top 80% of water users in the City of Johannesburg Metropolitan region



4.5 EKURHULENI METROPOLITAN COUNCIL (East Rand)

No data on water use or effluent volumes were received from the Ekurhuleni metropolitan council.

4.6 eTHEKWINI WATER AND SANITATION (Durban)

In the eThekwini Metropolitan area, 58% of the effluent was produced by the paper and paper products sector followed by the production of petroleum products (18%), textile industry (15%) and beverages (9%) (**Figure 4-6**). It is interesting to note that the largest effluent producer is not the largest water user. Textiles used 36% of the water and produced 15% of the effluent, whereas the manufacture of paper and paper products used only 17% of the water but produced 58% of the effluent.

Table 4-1: An extract from the data obtained from eThekwini water and sanitation

Industry type	**Water Consumption (kℓ/month)**	**Effluent (kℓ/month)**
Textile	13787	10360
Chemical	49740	11280
Textile	21000	14137
Dyeing and colouring	15960	14227
Textile	21855	15814
Beverages	35096	16173
Textile	20415	16204
Manufacture of food	23128	16666
Manufacture and refining of sugar	26850	19699
Cleaning and toilet preparations and cosmetics	19250	14438
Laundry/washery	17369	16452
Textile	34250	25244
Recycling	ND	26975
Textile	41285	28299
Dairy	43170	31358
Beverages	36818	32793
Automotive	ND	34554
Manufacture and refining of sugar	ND	76425

Poultry	99651	90094
Beverages	ND	90709
Petroleum and petroleum products	ND	129894
Textile	140272	139234
Petroleum and petroleum products	196413	164872
Manufacture of paper and paper products	133898	925705

ND = Not determined

Figure 4-5: Top 80% of water users in the eThekwini Metropolitan region

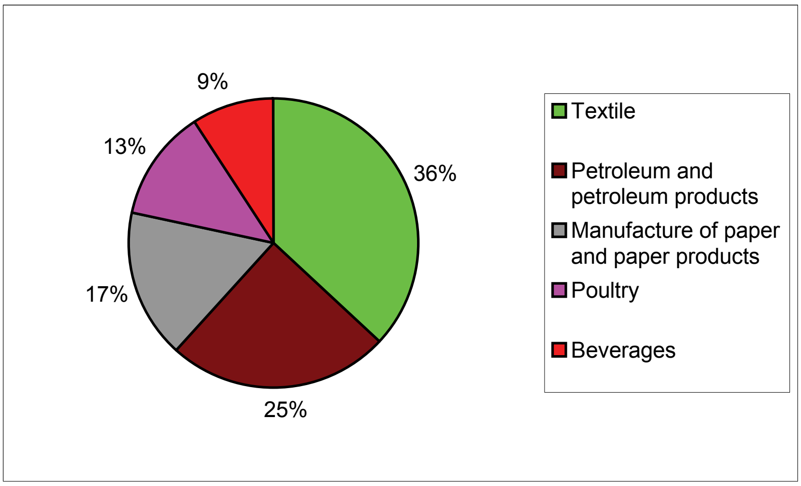
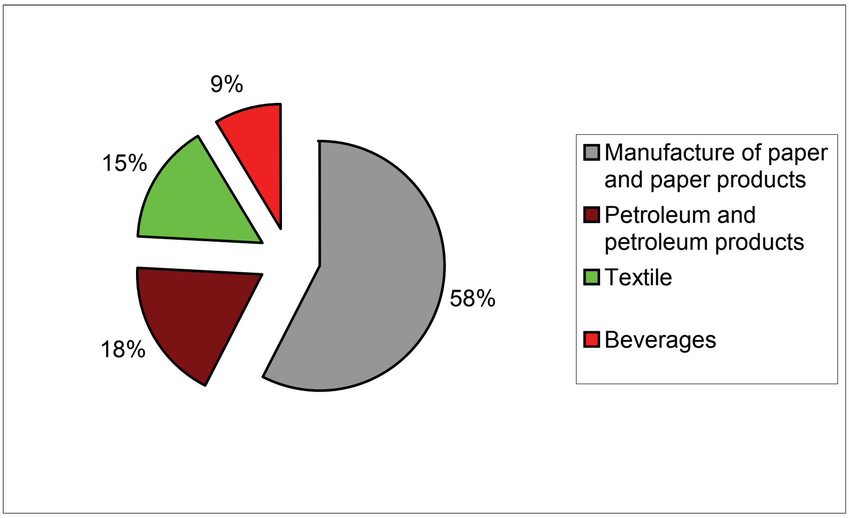


Figure 4-6: Top 80% of effluent producers in the eThekwini Metropolitan region



4.7 NELSON MANDELA METROPOLITAN COUNCIL (Port Elizabeth)

In the Nelson Mandela Metropolitan area the water related focus was again the breweries. Here, 42% of the effluent was produced by the breweries, followed by the automotive industry (21%) the textile industry (12%), the food manufacturing industry (8%) and the tannery industry (8%).

Table 4-2: An extract from the data obtained from Nelson Mandela Metro

Industry type	Annual Water Consumption (kℓ)	Annual Effluent production (kℓ)
Brewery	114 935	74 708
Chemical	32 628	1 631
Diary	22 490	14 169
Automotive	22 328	9 154
Textile	21 415	20 345
Manufacture of food	18 640	15 471
Manufacture of paper and paper products	16 304	13 043
Tannery	15 265	9 159
Automotive	14 409	9 366
Accommodation	12958	12 310
Automotive	11 599	11 019
Pharmaceutical	10 767	9 152
Fruit processing	10 484	9 960
Tannery	6 998	4 059
Automotive	6 855	6 512

Figure 4-7: Top 80% of water users in the Nelson Mandela Metropolitan region

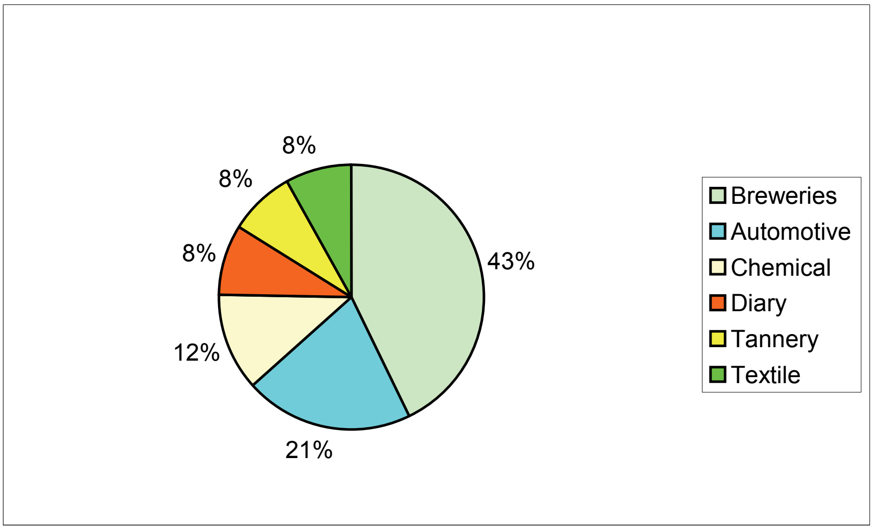
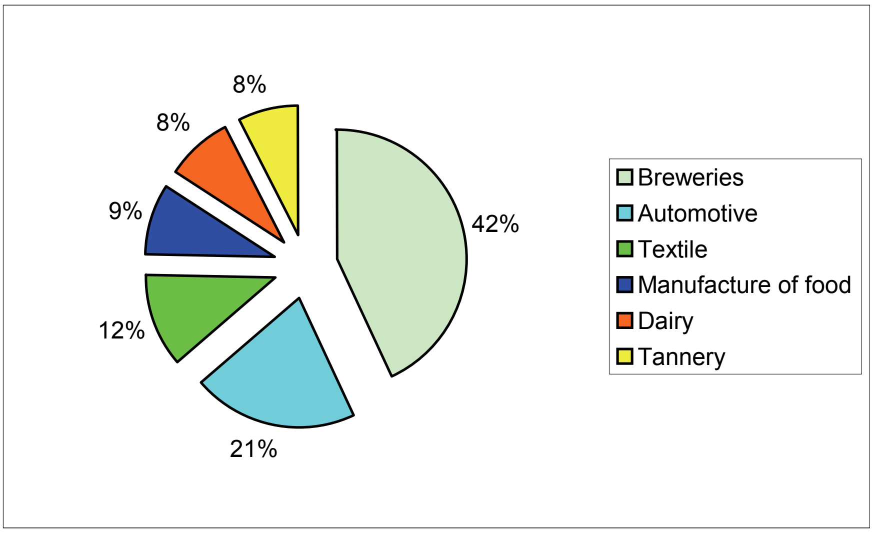


Figure 4-8: Top 80% of effluent producers in the Nelson Mandela Metropolitan region



4.8 TSHWANE METROPOLITAN COUNCIL (Pretoria)

The Tshwane metropolitan area was also dominated, from an industrial water related perspective, by the breweries industry. Here 81% of the effluent production was attributed to breweries, followed by food manufacture (11%) and the textile industry (8%) (**Figure 4-10**). Similarly, breweries were the largest industrial water user (64%) with the balance of the water being used in recycling, beverages, textiles, food manufacturing and canning (**Figure 4-9**).

Figure 4-9: Top 80% of water users in the Tshwane Metropolitan region

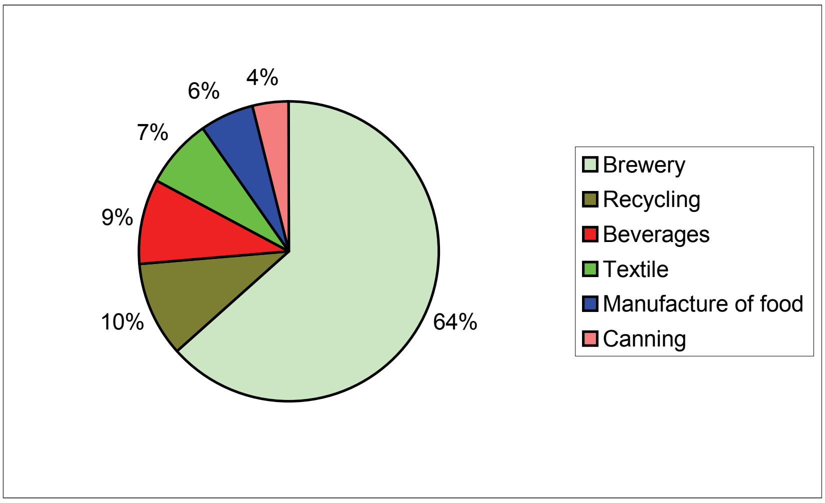
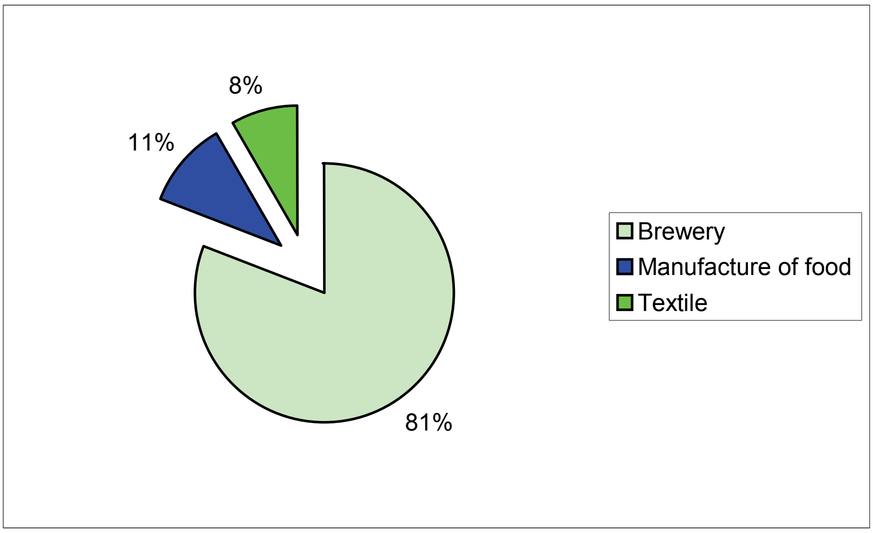


Figure 4-10: Top 80% of effluent producers in the Tshwane Metropolitan region



4.9 DWAF: KZN REGIONAL OFFICE

Information on registered companies that discharge wastewater was also obtained from the Department of Water Affairs Regional office in KwaZulu-Natal. The database they provided us with proved to be quite extensive with regard to billing rates and particulars of companies. The effluent volumes given in the database proved to be of considerable value to this project, as it assisted the project team in identifying companies to be contacted in order to obtain detailed effluent data.

4.10 GENERAL COMMENTS

The data obtained from the various metropolitan councils differed considerably with regard to level of detail and units. At present there is no system in place to regulate the level of detail that metropolitan councils should go to in obtaining information on effluent production (especially with regard to chemical composition) and as a result, the data obtained from the metropolitan councils was inconsistent and comparisons were not always possible. In many of the cases the extent to which chemical analyses are being done on the effluent should be reconsidered so as to facilitate the process of fully appreciating the risks associated with it. Another aspect of the metropolitan data that may be improved upon is the mechanism for and extent to which existing information is made available.

The quality of effluent is not the only consideration to be taken into account when it comes to the estimation of environmental threats that the effluent may hold. Other important considerations are the volume and the destination of the effluent. In this respect, despite the incomplete nature of the sample, the metropolitan data analysis was very informative. From these data sets, a number of general trends in water use and effluent volume production were observed.

It is interesting to note that whenever there was a brewery within a metropolitan area, it was usually the major user of water. The brewery industry was also the major contributor to effluent produced in the metropolitan regions.

Other important sectors in the metropolitan areas that produced large quantities of effluent were the pulp and paper industry and textile industries.

The food and beverage industry as a whole was also a significant producer of effluent in the sense that this industry was by far the most common industry present in all the metropolitan areas and it contributed significantly to the production of effluent.

5 SECTORAL WATER USE AND EFFLUENT PRODUCTION FOR SPECIFIC INDUSTRIES

5.1 INTRODUCTION

WRC's Key Strategic Area for Water Use and Waste Management (KSA 3) is responsible for identifying and investing in research to address problems associated with all water use and waste production outside of agriculture and forestry. In order to identify and prioritise those facets that need most urgent attention, it is important to quantify the water use and waste production by different sectors. Without such information it is, for instance, difficult to know whether the present investment in research in this KSA and more specifically the Thrust on Industrial and Mine-water Management, has the right mix. Such information is also necessary to provide strategic direction to research initiatives and to ensure that all important research areas are receiving the required attention.

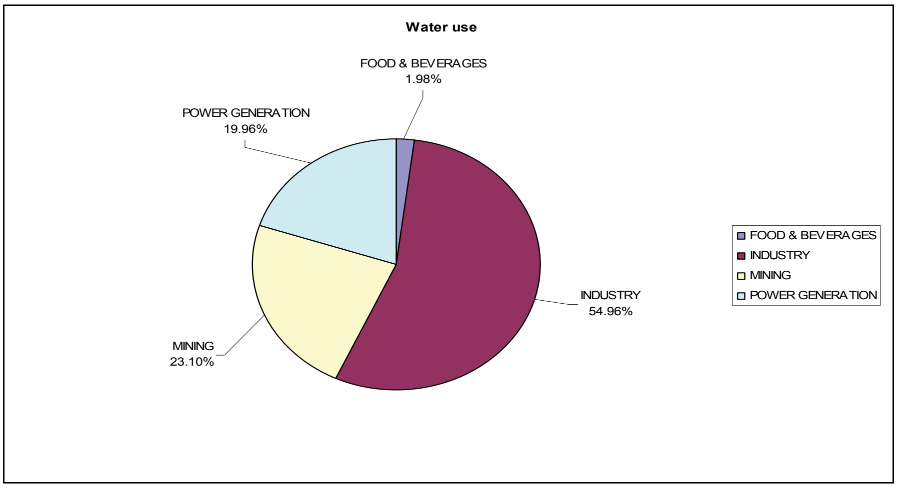
Using the metropolitan databases on water users, specific industries were identified and additional information was requested from these on production processes, production figures, water use, effluent volumes and effluent quality. Not all of the organisations contacted were helpful in providing this information – their main concern being confidentiality.

The data obtained for this first order inventory originated from a number of different sources. The type of information received from the various sources also differed, mainly due to limited monitoring and reluctance on behalf of both public and private organisations to make available sensitive information.

5.2 OVERALL WATER USE AND EFFLUENT PRODUCTION FOR ALL SECTORS

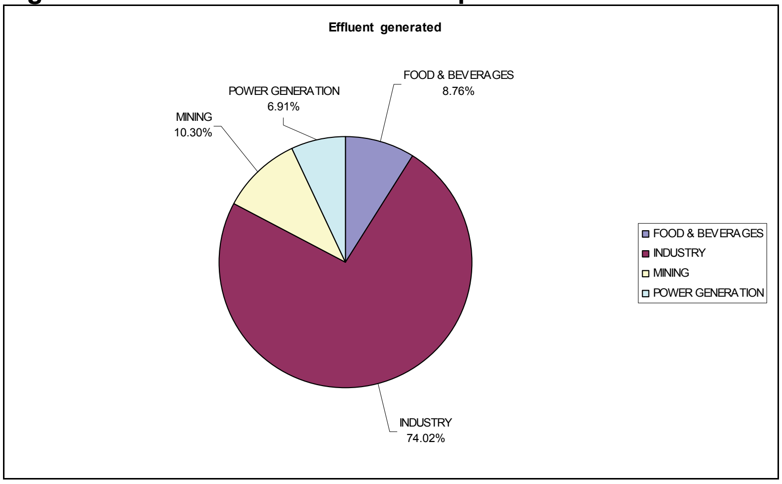
The Industry sector used 55% of the total water usage followed by Mining (23%) Power generation (20%) and Food and beverages (2%) (**Figure 5-1**).

Figure 5-1: Overall sectoral water use



Regarding effluent production, the Industry sector produced the largest volume of wastewater (74%) followed by Mining (10%), Food and beverage (8%) and Power generation (7%) (**Figure 5-2**).

Figure 5-2: Overall sectoral effluent production



5.3 INDUSTRY SECTOR WATER USE AND EFFLUENT PRODUCTION

Table 5-1: Industry – water use and effluent release

Source	Annual water consumption (Mm³)	Annual effluent production (Mm³)
Cement	4.6543	0.1827
Chemical	0.7419	0.1369
Cleaning	0.7460	0.3143
Dye and colouring	0.8955	0.6450
Ferrous Metals	133.78	1.5639
Plastics	0.0033	0.0000
Paint	0.0203	0.0005
Petroleum	136.26	23.617
Pulp & Paper	44.063	39.488
Tannery	0.1707	0.0135
Textile	5.0511	3.1146
Washery / Laundry	0.2340	0.2186
TOTAL	326	69

The three industries that used most of the water (large users) were the Petroleum Industry (41,72%) fallowed by the Ferrous Metals Industry (40,96%) and the Pulp and Paper Industry (13,49%). These three industries made up more that 90% of the industry water users (**Figure 5-3**).

Figure 5-3: Industry: water usage

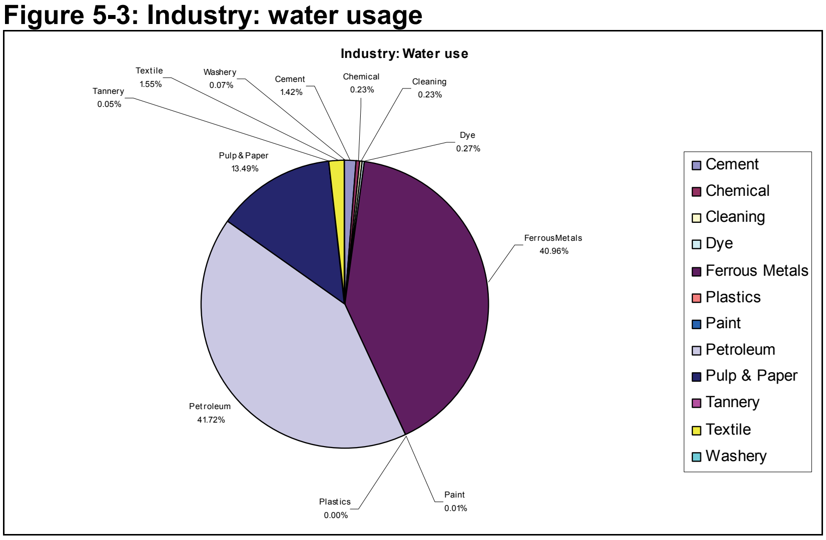
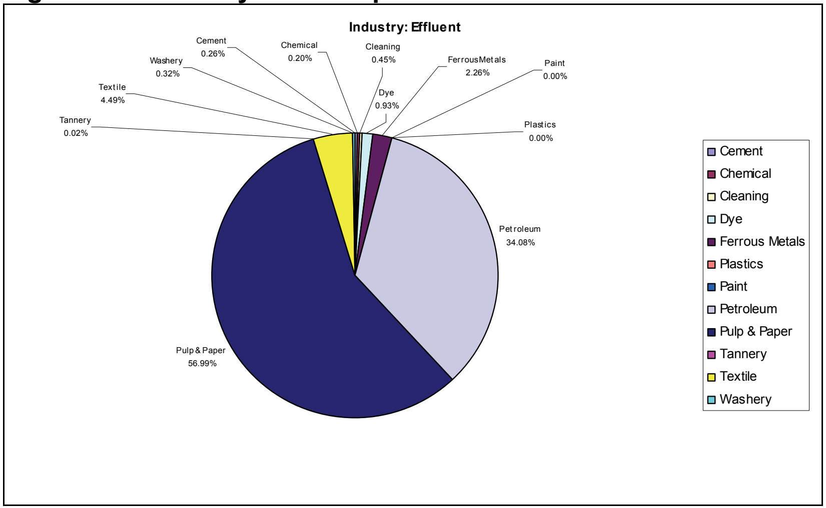


Figure 5-4: Industry: effluent production

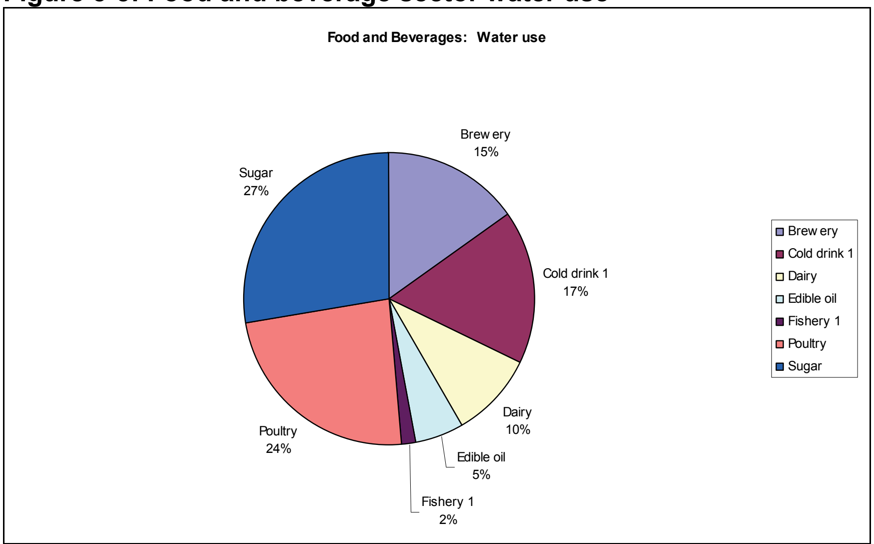


In terms of industry effluent production, the Pulp and Paper Industry produced 56% of the effluent followed by the Petroleum Industry (34%) and Textile industry (4%). From this survey the Petroleum and Pulp and Paper Industries produced 90% of the effluent (**Figure 5-4**).

5.4 FOOD AND BEVERAGE WATER USE AND EFFLUENT PRODUCTION

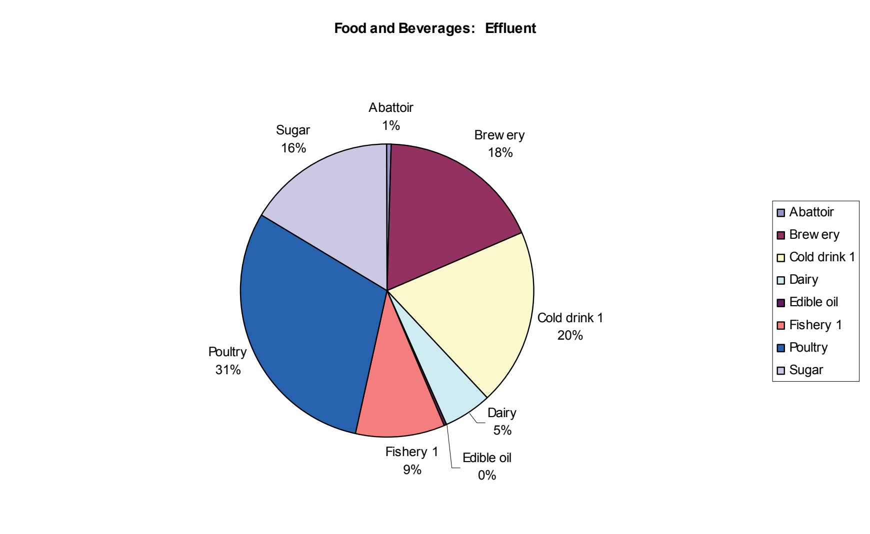
The top 5 water users in the food and beverage sector were, Sugar (27%) followed by Poultry (24%), Cold Drinks (17%), Breweries (15%) and the diary sector (10%). These industries accounted for more that 90% of the water use (**Figure 5-5**).

Figure 5-5: Food and beverage sector water use



In terms of effluent production, the Poultry industry was at the top of the list (31%) followed by Cold Drinks (20%), Breweries (18%) and the Sugar industry (16%) (**Figure 5-6**).

Figure 5-6: Food and beverage effluent production



5.5 GENERAL COMMENTS

When considering the total quantity of water used, the Industry Sector consumed 55%, followed by mining (23%) and power generation (20%) and then the food industry at 2%. The total effluent production followed a similar trend to usage, with the industry sector at 74%, mining at 10%, food and beverage at 9% and the mining sector at 7%. It is quite obvious that the industry sector accounted for more than 50% of the water used and more than 74% of the effluent produced. In terms of water use, the three leading industries were petroleum (42%), ferrous metals (41%) and pulp and paper (14%). Regarding effluent production, pulp and paper took the lead at 57%, followed by the petroleum industry at 34%. These two industries accounted for more than 90% of the industrial effluent produced.

In terms of water risk analysis, it was obvious that the petroleum industry and the pulp and paper industry potentially poses the greatest risk in the industry sector and in fact overall taking all sectors into account. From the data, mining and power generation and the food and beverage sectors produce similar quantities of wastewater. In terms of risk based on the chemical composition of the waste, the mining sector poses the greatest potential risk followed by the food and beverage sector and then power generation. The five most important food and beverage groups in terms of water use and effluent production were Sugar (27%), poultry (24%), cold drink (17%), breweries (15%) and dairies (10%) in terms of water use, and in terms of effluent production, poultry (31%) followed by cold drinks (20%), breweries (18%), sugar (16%).

Table 5-2: The ranking of the top water users

Sector	Percentage
Industry	54%
1. Petroleum	
2. Ferrous metals	
3. Pulp and paper	
Mining	23%
Power generation	20%
Food and beverage	2%
1. Sugar	
2. Poultry	
3. Cold drinks	
4. Brewery	
5. Dairy	

Table 5-3: The ranking in terms of effluent production would therefore be.

Sector	Percentage
Industry 1. Pulp and paper 2. Petroleum 3. Textile	74%
Mining	10%
Food and beverage 1. Poultry 2. Breweries 3. Cold drinks 4. Sugar	9%
Power generation	7%

All of the above are significant water users and effluent producers. Due to the lack of detailed information on the effluent composition in most cases, it was difficult to single out specific industries as posing a higher risk than others. Hence the volume (quantity) of wastewater produced should act as a guiding principle in terms of prioritizing research needs. In this respect, a more detailed investigation will need to be conducted in all of the above-mentioned industries, to determine the risk and to research mitigation strategies.

6 EFFLUENT RISK ASSESSMENT FOR EACH SECTOR

6.1 INTRODUCTION

The risks associated with certain chemical constituents in the effluent relevant to industries of all the sectors covered in this study, will be discussed both generically and individually.

An important consideration in determining the risk of a particular effluent is the point of discharge. The impact would, for example, be far greater if effluent were to be discharged into the natural environment than if the effluent were to be discharged into a municipal sewerage works. During this study it was not always clear where the effluent was being discharged. In some instances it was not clear whether the effluent was first treated prior to discharge. The need to respect confidentiality presented some difficulties in the sense that even if the name of the organisation was withheld, the disclosure of details such as the spatial distribution of certain industry type and associated effluents would enable someone to make logical deductions regarding the organisation involved.

Although information was obtained from numerous companies in the industrial, food and beverage, mining and electricity generation sectors, the majority of the companies contacted did not perform analyses for the full spectrum of hazardous substances in the effluent. As a result, these companies could not give account of the exact composition of the wastewater resulting from the industrial activity.

Due to the lack of sufficient data, professional opinions were solicited for each sector, in terms of the potential risks.

6.2 GENERIC EFFLUENT RISKS

6.2.1 Organic matter

Wastewater components can be divided into different main groups (Table 6-1). Specific constituents of effluent are discussed, referring to various aspects regarding the risks they pose to the environment.

The river water pollution load is indicated by its biochemical oxygen demand (BOD) concentration. BOD is a measure of the amount of biodegradable organic substances in the water. As naturally occurring bacteria consume these organic substances they take up oxygen from the water for respiration, while converting the substances into energy and materials for growth. On average each person produces about 60 g of BOD in faecal and other materials. This is equivalent to 60,000 mg of BOD. Depending on the volume of water used to convey the faecal materials, the concentration of the BOD in the wastewater varies. The river pollution classification provides an illustration of the ability of the environment (here the river) to cope with small waste discharges of organic wastes. The river water at low levels can only dilute small discharges of BOD. If the concentration of BOD in the river water is less than 3 mg/l the river remains ‘unpolluted’. The continuous transfer of oxygen from the atmosphere to the water helps bacteria consume the organic wastes and replenishes the oxygen uptake by bacteria. The dissolved oxygen (DO) concentration in the water remains high. Other physical, chemical and biological processes take place, which help nature to purify wastes. It does not take much for an unpolluted river to become a grossly polluted river. When the BOD concentration in the river water is greater than 12 mg/ℓ, the transfer of oxygen from the atmosphere cannot replenish the oxygen demand and the water becomes completely deoxygenated (anaerobic). It is incapable of supporting fish life. If the water is dominated by heterotrophic bacteria that thrive on organic wastes and are able to extract oxygen chemically from substances like sulphates in the wastes then gases such as hydrogen sulphide (rotten egg gas) and methane are generated. Foul odours are the result, and the appearance of the water is grey-black with bubbles frothing up.

Table 6-1 Components present in wastewater and their environmental effect

Component	Of special interest	Environmental effect
Micro-organisms	Pathogenic bacteria, virus and worms eggs	Risk when bathing and eating shellfish
Biodegradable organic materials (BOD)	Oxygen depletion in rivers and dams	Fish death, odours
Other organic materials	Detergents, pesticides, fat, oil and grease, colouring, solvents, phenols, cyanide	Toxic effect
Nutrients	Nitrogen, phosphorus, Ammonium	Eutrophication, oxygen depletion Toxic effect
Metals	Hg, Pb, Cd, Cr, Cu, Ni	Toxic effect, bioaccumulation
Other inorganic materials	Acids	Corrosion, toxic effect
Thermal effects	Hot water	Changing living conditions for flora and fauna
Odour (and taste)	Hydrogen sulphide	Odours toxic effect

6.2.2 Heavy metals

Since the onset of industrialization, the deposition of heavy metals into the natural water environment has altered the cyclic fluctuations of metal and trace elements previously found therein. The toxicity of these metals in natural waters results from a combination of their solubility, bio-availability and the effect on the organism at a cellular level. The major sources of metal pollution into aquatic ecosystems include domestic wastewater effluents, coal burning power plants, non-ferrous metal smelters, iron and steel plants, mine and metal finishing industries and the dumping of sewage sludge.

6.2.3 Simple phenols

Phenols are fairly ubiquitous as pollutants, appearing in wastewater streams from numerous industrial processes, including petroleum refining, petrochemical manufacture and coking and coal conversion industries, resins and plastics, dyes and other organic chemicals, textiles, timber, mining, and the pulp and paper industry (Klein and Lee, 1978; Atlow, 1984; Van Schie and Young, 1998). A South African process for conversion of coal to oil produces, in particular, two phenol-containing effluents, known as black product and cresylic effluent. These contain phenolics, mostly in the form of phenol and the cresols.

The release of large quantities of phenolic wastewater can create considerable eco-toxicological problems with serious consequences for human health and for all living organisms (Alberti and Kilbanov, 1981). Phenol itself is toxic to most micro-organisms. It can be inhibitory to the growth of even those species that have the metabolic capacity of using it as a carbon source, and it can be toxic or lethal to fish at concentrations as low as 5-25 mg/ℓ. It also contributes to off-flavours in drinking and food-processing waters. Although phenol is not bio-accumulative, humans exposed to phenol at concentrations of 1300 mg/ℓ present symptoms of diarrhoea, mouth sores, dark urine and burning of the mouth (Annachhatre and Gheewala, 1996).

6.2.4 Sulphates and acid mine drainage

Many industries, especially mining companies, are faced with serious problems caused by effluent containing high concentrations of sulphate, heavy metals and low pH. The extent of Acid mine drainage (AMD) impact on the environment may vary from the restricted pollution of small streams to quite profound perturbations of geo-hydrological systems on a regional basis (Rose, 2002). Apart from

adding substantial costs to water provision and consumers, the salt load from mining activities has contributed significantly to the salinisation of downstream irrigation land (Rose, 2002). The heavy metal concentrations present in the effluent are toxic to all biota and the acidic pH disturbs the ecological systems maintained in the receiving waters (Gray, 1997). AMD is therefore categorized as a multi-factor pollutant (Gray, 1997). AMD is a term used to describe leachate, seepage, or drainage that has been affected by natural oxidation of sulphide minerals contained in rock that is expose to air and water (Atlas and Bartha, 1993).
Because of the biological entities involved in AMD formation, preventative control efforts have been developed that specifically target this component (Ledin and Pedersen, 1996). However, surfactants and slow release biocides become diluted after time rendering it ineffective. Another effective method of preventing AMD formation is to separate the sulphide-bearing rocks from air and water (Ledin and Pedersen, 1996). These include covering the rocks with air and water repulsing clay, vegetating waste piles, and placing the rocks on specially engineered sites that allow capture and treatment of the effluent (Bruerly and Brierly, 1997).

The chain of chemicals responsible for the formation of sulphuric acid from sulphate can be interrupted by the removal of the sulphate. Sulphate may be removed using processes such as reverse osmosis and electro dialysis (Maree and Strydom, 1987). These methods are very costly and maintenance intensive. The drainage water itself can be treated by the addition of alkaline chemicals or by constructing artificial wetlands (Lendin and Pederson, 1996).

There is an increasing demand for inexpensive environmental friendly technologies to remediate AMD. The use of sulphate reducing bacteria (SRB) in the biological removal of sulphates is such an alternative. SRB can oxidize organic compounds like lactate and acetate, if a suitable electron donor is available (Dill et al., 1994). During this process, sulphate is used as an electron acceptor and reduced to sulphide. Various experiments using different bioreactor set-ups have been studied for potential use in the biological removal of sulphate by SRB (Tuttle et al., 1969, Maree and Strydom, 1985; Du Preez et al., 1991; Van Houten et al., 1994).

6.2.5 Phosphates and nitrates

Eutrophication of South Africa's natural waters is greatly accelerated by human activities, resulting in the discharge of the nutrients nitrogen (N) and phosphorus (P). Nutrients are introduced into the water from point sources, e.g. wastewater treatment works, and diffuse sources, e.g. from fertilizers or the excreta of animals and birds (Lilley et al., 1997). Phosphate is recognised as one of the major nutrients contributing to the eutrophication of aquatic environments (Momba and Cloete, 1996a,b). Gross eutrophication is marked by large visible blooms of algae that make water treatment difficult (Atlas and Bartha, 1993; Lilley et al., 1997). Degradation in the water quality of lakes is noticed by an offensive odour, appearance, taste, as well as depletion of oxygen from the lower water, resulting in extensive fish kills. Many algae have the ability to fix nitrogen in water and therefore phosphorus is the element that should be restricted in order to minimize eutrophication (Lilley et al., 1997). Sources of phosphorus include fertilizers, synthetic detergent and excreta. In the United States of America the concentration of phosphate in raw municipal wastewaters has been significantly reduced by the implementation of detergent "phosphate bans" (Martin and Wilson, 1994). Phosphate is a major component of nucleic acids and therefore no organism can reproduce without phosphate. Phosphate is however a limiting nutrient, and therefore the removal of phosphate from effluents should limit one of the basic causes of eutrophication or algal blooms (Momba, 1995).

Key parameters for policy compliance include toxicity, colour and total dissolved solids (TDS). Discharges should not display acute or chronic toxicity; discharges should not cause objectionable colours in receiving waters; and TDS levels in receiving waters should not be increased unacceptably. To ensure policy compliance, wastewater quality should be comparable with that of the receiving waters. This would be likely to require a treatment regime combining processes such as sedimentation, chemical dosing, dissolved air flotation, biological oxidation and filtration. The capital and operating costs of such complex treatment processes may be significant. These processes also generate sludge, which requires an environmentally sound disposal route.

6.3 SPECIFIC SECTORAL EFFLUENT RISKS

6.3.1 Cement manufacturing

6.3.1.1 Production

Risks associated with cement manufacturing are discussed using data from two cement-manufacturing companies, called Cement 1 and Cement 2, for confidentiality purposes.

To produce cement, Cement 1 use limestone together with an alumina and iron additives. Cement 1 currently utilise two clinker-producing lines as well as two finish grinding mills. Most of the water consumption is attributable to the gas conditioning process, which is used to condition the pre-heater exit temperatures. The waste gases from the pre-heater exit ducting pipes are mostly used as a drying hot gas to evaporate moisture in the raw material feed entering the raw mills, which is back stream of the clinker producing lines. The kiln lines run separately from the raw mill circuits. The raw mill circuits are utilised as much as 80% of the kiln running time. When the raw mill is not running, the raw mill circuit is bypassed and the hot gas is then conditioned to an even lower temperature, where the waste gases are first passed through an electrostatic precipitator de-dusting process before it is eliminated as relatively clean air via the stack. The kiln production lines are referred to as kiln lines 2 and 3. Kiln line 1 is mothballed and is not being used for production purposes. Additional water is used to control the temperature of the cement in the final cement milling operations. The operations mentioned above use water, which is being pumped from the site quarry dam. The water being used for general household and drinking purposes is being extracted from a borehole nearby.

6.3.1.2 Effluent risk assessment

Water use and effluent production data, as obtained from Cement 1 is given in **Table 6-2** and **Table 6-3**. Annual water use data was obtained from Cement 2 and is given in **Table 6-4** below. The total volume of effluent from Cement 2 is not measured. However the effluent is only water as the cement process is a dry process. They have no water purification plants.

Table 6-2: Cement 1 Water Consumption

	Consumption /hr	Consumption /day	Consumption /year
Average water consumption used to condition gases in kiln 2	20 m^3/hr	480 m^3/day	126 144 m^3/year @ 0.72 UF
Average water consumption used to condition gases in kiln 3	25 m^3/hr	600 m^3/day	175 200 m^3/year @ 0.80 UF
Subtotal for Gas Conditioning:			301 344 m^3/year (UF included)
Water used to control cement temperatures (mill 1)	3 m^3/hr	72 m3/day	19 710 m^3/year @ 0.75 UF
Water used to control cement temperatures (mill 2)	3 m^3/hr	72 m^3/day	19 710 m^3/year @ 0.75 UF
Subtotal Including Milling:			340 764 m^3/year (UF included)

* UF = Utilization Factor

Table 6-3: Cement 1 Total Volume of Water Used

YEAR	m^3
2001	198 877
2002	249 825
2003	363 061
2004	98 800

Table 6-4: Cement 2 Water consumption at locations

Location 1-10	Annual water use (kℓ)
1	448 545
2	57 926
3	72 737
4	383 392
5	667 470
6	331 682
7	24 984
8	1 412 896
9	17 146
10	516 356

The priority in the cement industry is to minimise the increase in ambient particulate levels by reducing the mass load emitted from the stacks, from fugitive emissions, and from other sources.

Normally, effluents requiring treatment originate from cooling operations or as storm water. Treated effluent discharges should have a pH in the range of 6-9. Cooling water should preferably be recycled. If this is not economical, the effluent should not increase the temperature of the receiving waters at the edge of the mixing zone (or 100 meters, where the mixing zone is not defined) by more than 3º Celsius.

If quantities of suspended solids in the effluent are high in relation to receiving waters, treatment may be required to reduce levels in the effluent to a maximum of 50 milligrams per litre (mg/ℓ). Note that the effluent requirements are for direct discharge to surface waters.

6.3.2 Chemical production

6.3.2.1 Effluent risk assessment

Risks associated with chemical production are discussed using effluent data from a chemical production company, called Chemical 1 (**Table 6-5)** as well as using information regarding typical effluent production and effluent chemical constituency obtained from the metropolitan councils of Durban (**Table 6-6**), Cape Town (**Table 6-7**) and Tshwane (**Table 6-8**).

Table 6-5: Chemical 1 Effluent data

	Raw effluent (mg/ℓ)	Final treated effluent (mg/ℓ)
Zn	504	34
Cr	14	<1
Cu	4	<1
Fe	848	<1
Pb	13	<1
Mn	17	8.55
Ni	3	2.81
Al	21	<1
NH3/N	160	132
TSS	160	206
COD/O2	2950	897
pH	1	8

Table 6-6 Extract of data for chemical industry effluent (Durban)

Date	COD	EC	Mineral oils	pH	Sulphate	Sulphide
	mg/ℓ	mS/m	mg/ℓ	-	mg/ℓ	mg/ℓ
2004/05/02	559	55	107	8	49	<1
15/04/2004	259	74	7	10	28	<1
2004/06/05	109	35	1	9	14	<1
2004/02/06	1800	143	4	9	75	<1
14/07/2004	1116	94	6	9	20	<1
16/08/2004	480	54	2	7	24	<1
2004/08/09	3200	100	6	7	55	<1
2004/04/10	518	44	6	9	39	<1
2004/04/11	972	108	8	6	213	<1
2004/08/12	3600	317	2	9	206	

EC = Electrical conductivity

Table 6-7: Extract of data for chemical industry effluent (Cape Town)

Industry type	COD (mg/ℓ)	pH	EC (mS/m)
Chemicals	12079	11	492
Chemicals	1 579	9	193
Medical chemicals	7672	11	1500

EC = Electrical conductivity

Table 6-8: Extract of data for chemical industry effluent (Tshwane)

Industry type	COD (mg/ℓ)	Ammo-nia (N) (mg/ℓ)	Nitrite/ Nitrate (N) (mg/ℓ)	Phosp hate (P) (mg/ℓ)	pH	EC (mS/m)
Pharmaceutical chemicals	217	1	0	0	7	58

EC = Electrical conductivity

The chemical effluent risk rests in the high COD concentrations and the alkaline pH. As far as Chemical 1 is concerned heavy metal residuals poses a potential problem. The toxicity of heavy metals is directly related to solubility. At acidic pH the heavy metals exist as free metal ions. Around neutral pH some may precipitate as hydroxides. Heavy metals have a deleterious effect on organisms when present in concentrations above that in the natural environment.

Depending on the biodegradable fraction of the COD, termed the biological oxygen demand (BOD) the concentrations in the chemical effluent will have a negative effect should the effluent be disposed of in natural waterways, especially taking into consideration the very high pH value.

6.3.3 Cleaning and toilet preparations and cosmetics manufacturing

6.3.3.1 Production

Home care products such as sources and dish wash liquids, are water based. The other ingredients are chemical actives, perfumes and colorants.

6.3.3.2 Effluent risk assessment

Risks associated with cleaning and toilet preparations and cosmetics manufacturing are discussed using information regarding the chemical analysis of typical cosmetic industries in Cape Town (**Table 6-9**) and Tshwane (**Table 6-10**).

Table 6-9: Chemical analysis of cosmetics industry effluent (Cape Town)

COD (mg/ℓ)	pH	EC (mS/m)
2 134	8	43.75

EC = Electrical conductivity

The effluent indicates COD values ranging from 2134 to 8477 mg per litre. This would have a major negative impact on the natural water environment, leading to oxygen depletion. The phosphate concentration was 55 mg/ℓ and the nitrate concentration 5 mg/ℓ. This would contribute significantly to eutrophication should the water be discharged into the environment. The pH of the effluent varied between 8 and 9.

Table 6-10: Chemical analyses of the cosmetics and cleaning preparations industry effluent (Tshwane)

Industry type	COD (mg/ℓ)	Ammonia (N) (mg/ℓ)	Nitrite/ Nitrate (N) (mg/ℓ)	Phosphate (P) (mg/ℓ)	pH	EC (mS/m)
Polish production	4 850	36	5	55	9	333
Soap	8 477	3	0	55	9	412

EC = Electrical conductivity

6.3.4 Dyeing/Colouring

6.3.4.1 Production

Generally, dyes are synthesised in a reactor, filtered, dried and blended with other additives to produce the final product in the dye manufacturing industry. The dyes are then separated from the mixture and purified. Unfortunately, salt (NaCl), small molecular weight intermediates and residual compounds are produced from the synthesis process. These salt and residual impurities must be removed before the dyes are dried for sale as powder because they reduce the purity of the dyes. Conventionally, the dye is precipitated from an aqueous solution using salt and the slurry is then passed through a filter press.

The dye is retained by a filter press and the filtrate containing salt and small molecular weight residuals from chemical reactions is discharged. The retained dye is collected in trays and dried in ovens. The dried dye is then pulverised to produce a saleable product. The purity of the final dye product from the conventional process is low, about 30% salt content; further, the conventional manufacturing process is carried out in various baths which makes the entire process very labour intensive and causes inconsistency in the production quality. Reactive dye manufacturing process is among the largest amount of water intensive processes in dye production. Reactive dyes normally have a low rate of fixation and have high loss to the effluent.

Natural dyes generally require a mordant, which are metallic salts of aluminium, iron, chromium, copper and others, for ensuring the reasonable fastness of the colour to sunlight and washing. Quality standards for natural dyes vary widely. Natural dyes are a class of colorants extracted from vegetative matter and animal residues.

6.3.4.2 Effluent risk assessment

Risks associated with dying/colouring are discussed using information regarding typical effluent chemical constituency obtained from the metropolitan council of Cape Town (**Table 6-11**).

Table 6-11: Dye industry effluent data (Cape Town)

Industry type	COD (mg/l)	pH	EC (mS/m)	Cl (mg/l)
Clothing / Dye House	217	10	347	1590
Textiles (spinners and dye)	1 992	12	1234	NA

NA = Not available
EC = Electrical conductivity

Wastewater produced from the dye manufacturing processes and liquid effluents can contain toxic organic residues. Generally, the wastewater generation ratio is in order of 1-700 l/kg of product. Furthermore, the wastewater characteristics in a particular dye house can be highly variable from day to day and hour to hour, depending on the type and colour of dye.

Dye manufacturing process wastewater included a high chemical oxygen demand (COD) (217-1992 mg/l) (**Table 6-11**). For a Category 2 to 3 Industrial Water Use, the chemical oxygen demand concentrations should preferably be less than 50 mg/l (DWAF, 1996). Overall the pH of the effluent was very alkaline (**Table 6-11**). The pH of most of the effluent samples ranged from neutral (pH 7) to alkaline (pH < 10) to highly alkaline (pH 11-12).

Effluent treatment of the dye manufacturing process conventionally includes neutralisation, flocculation, coagulation, activated carbon absorption, advanced oxidation using UV systems or H_2O_2 solutions, and biological treatment. Where this is not the case, the effluent poses a threat to natural water systems.

6.3.5 Ferrous metals manufacturing

Chemistry: The plating operation involves the handling and close proximity to toxic and carcinogenic chemicals (particularly, cyanide, cadmium, nickel and chromium VI). An effective extraction system is in place, which greatly reduces the risk of worker exposure. However there is a degree of fumes within the plant that result in irritation to the nose and throat and may be due to faults in the extraction system, which may not be well maintained, or additional ventilation/extraction, may need to be installed.

Temperature: The plant is well aired and the roof is sufficiently high above the plant to prevent high temperatures during summer. It may be slightly cold during winter but acceptable.

Heavy lift: On line 3 the barrels are lifted using hoist cranes. This is true for the other lines as well so the staff requires no lifting of barrels/jigs.

Virtually the entire floor of the plant is covered by chemical drips/spills. The floor slopes and directs the drips/spills to trenches, which lead to the WWTP. This represents a health hazard, as dried salts may be rendered airborne by wind and pedestrian traffic, while spills can lead to slipping. Apart from these direct hazards, if the liquid seeps through the concrete floor, it can reach ground and even groundwater tables where any contamination may be hazardous to surrounding areas and communities. The floor does need resealing in some areas. A new floor made from shot blast wastes and resin may be more cost-effective (used in Durban metal finishing plants). Management intends to put in new sumps and pipes in place of the poorly sloping floor to WWTP, and this is highly recommended. It must be noted that the aim is reduction at source and all effort should be made to prevent spills/drips to floor in the first place.

The following areas have a medium to high potential for improvements and for implementation of cleaner production strategies to improve the environmental performance and obtain further waste and cost reductions:

- Water consumption and associated rinsing system
- Chemical use in waste water treatment plant
- Consumption of process chemicals
- Maintenance/operation of process baths to prolong their lifetime
- Solid waste minimisation

The performance indicator for each assessment factor is per annual m^2 plated. This figure is a key, yet it is not known accurately and has to be calculated from the estimated average plating thickness of 13 µm (zinc), and known anode consumption (12 t/a). With these inputs, surface area plated was calculated to be ~130,000 m^2/a. The plating manager estimated around 90,000 m^2/a but with the 12 tons Zn anode consumption this would mean a plating thickness of 19 microns, which appears too high. It is unclear where the value for anode consumption was obtained and should be checked. If not done so already, it is recommended to monitor and record actual anode consumption over time (instead of relying on purchasing records).

Table 6-12: Ferrous Metals – Discharge control parameters

Monitor parameter	**Period**		
Discharge Control	**Minimum**	**Maximum**	**Average**
Water, m^3/d (Line 3)			23
Water, m^3/a (Line 3)			7037
pH	2.92	9.83	6
Zinc, mg/ℓ	0.27	211	40
Chromium (VI), mg/ℓ	0.08	78	16
Copper, mg/ℓ	0	15	4
Nickel, mg/ℓ	0	72	17
Cyanide, CN, mg/ℓ			
Cadmium, mg/ℓ	0	2.24	0.5

There is no treatment for destruction of chrome (VI) since management claims that the concentrations of Cr in the effluent are too low to warrant treatment. The Cr in the Nickel/Cr line is reduced in a neutrachrome step prior to reaching the rinse water. In Line 3, the rinses after passivation may be highly diluted in the bulk volume, however the spent passivation solutions (which contain hexavalent chrome) are disposed regularly and this is a concern. It is recommended that prior to disposal to WWTP that these be batch treated for Cr reduction.

Alternative Cr-free or Cr(III) passivation chemical could also be investigated. Ideally Cr should be kept to a minimum in the wastewater by preventing drag-out and extending the life of Cr-containing baths as far as possible. Although Cr(VI) may be dilute in the effluent, the load may still be significant. It must be noted that Cr(VI) is a problem heavy metal in downstream sewage treatment plants due to the fact it cannot be removed in these and passes through, ending up in rivers where it is hazardous to aquatic life and a toxic carcinogen. It must therefore be recommended that all Cr-containing wastewaters be combined and treated with meta-bisulphite prior to joining the bulk effluent for metal precipitation.

The effluent stream, which is disposed of to sewer, is monitored monthly by the local municipality. Reports are provided to the company and detailed records are kept. Analysis of these records from 1999 to 2002 shows that the average Zn content is ~40 ppm. The readings are range from well below limit (<20 ppm) to very high values in some monthly tests (50-200 ppm). On these occasions, chrome content is very high as well.

The average chrome content (as Cr^{6+}) is 16 ppm which is very high (Cr(VI) should be <0.5 ppm while Cr in total should be <10 ppm). These high values are a big concern and should be investigated to identify the source and cause and prevent from occurring again. Both CN and ammonia are present in the effluent and these acts as complexing agents particularly with Ni and will inhibit metals removal. Attempts should be made to keep these segregated if at all possible. Lime is not able to precipitate heavy metals satisfactorily from the various metal complexes present in the effluent. The usage of lime will be affected if metal complexes are present.

6.3.6 Paint

6.3.6.1 Water use and effluent data

Risks associated with the paint industry are discussed using information regarding typical effluent chemical constituency obtained from the metropolitan councils of Cape Town and Tshwane (**Table 6-13** and **Table 6-14**).

Table 6-13: Chemical analysis of paint industry effluent (Cape Town)

COD (mg/ℓ)	**pH**	**EC (mS/m)**
1506	8	33.75

EC = Electrical conductivity

Table 6-14: Chemical analysis of paint industry effluent (Tshwane)

Industry type	**COD (mg/ℓ)**	**Ammonia (N) (mg/ℓ)**	**Nitrite/ Nitrate (N) (mg/ℓ)**	**Phosphate (P) (mg/ℓ)**	**pH**	**EC (mS/m)**
Powder paints	1093	1	0	40	9	195
Powder paints	161	4	3	0	8	45
Oil and water base paints	2362	7	2	2	7	38
Oil and water base paints	1823	1	1	5	7	36
Oil and water base paints	4205	11	1	10	8	50
Oil and water base paints	3054	13	1	27	6	149

EC = Electrical conductivity

6.3.6.2 Effluent risk assessment

The high COD will result in oxygen depletion should the effluent be discharged into a natural water system (**Table 6-14**). The relatively high ammonia and phosphate concentration will further contribute to nutrient enrichment and eutrophication (**Table 6-14**). The pH varied between 6 and 9 and the latter would also have a negative impact on the environment (**Table 6-14**).

6.3.7 Petroleum refineries and petroleum products

6.3.7.1 Production

The primary function of a petroleum refinery is to separate crude oil and convert it into products such as gasoline, diesel fuel oil, light and heavy fuel oils, petrochemical feedstock, aviation fuels, asphalt, liquefied petroleum gas (LPG), lubricants, kerosene and other products. Many sophisticated technological processes are used to literally break down and then recombine the molecules of the original crude oil to produce the desired end products.

Facilities require significant volumes of water for on-site processes (e.g. coolants, blow-downs etc.) as well as for sanitary and potable use. Wastewater will derive from these sources (process water) and from storm water run-off. The latter could contain significant concentrations of petroleum product. Petroleum hydrocarbons dissolved, emulsified or occurring as free-phase will be the key constituents although wastewater may also contain significant concentrations of phenols, amines, amides, alcohols, ammonia, sulphide, heavy metals and suspended solids. Wastewaters may be collected in separate drainage systems (for process, sanitary and storm water) although industrial and storm water systems may in some cases be combined. On-site treatment facilities may exist for wastewater or treatment may take place at a public wastewater treatment plant. Storm water/process water is generally passed to a separator or interceptor prior to leaving the site which takes out free-phase oil (i.e. floating product) from the water prior to discharge, or prior to further treatment, e.g. in settling lagoons).

A complex combination of many different unit petrochemical processes is used in a modern petroleum refinery to change crude oil physically and chemically in order to produce the various products in desired qualities and quantities. Various wastewaters are generated during the refining process. It is typical practice in most refineries to collect all process wastewaters and to combine them into a single waste water stream which is then treated in a central facility -often called "end-of- pipe" treatment .The end-of-pipe treatment technology in the petroleum refining industry relies heavily upon the use of biological treatment methods. Of all the biological wastewater treatment methods, the activated sludge process is the most cost-effective and widely used secondary treatment technique. One of the biggest challenges faced by activated sludge wastewater treatment plants arises from their operation and control problems.

6.3.7.2 Effluent risk assessment (http://www.atl.ec.gc.ca/epb/progs/petrol.html)

Potential contaminants in refinery wastewater originate from the crude oil, the intake water, storm water, ballast water from oil tankers, sanitary wastes, process chemicals and catalysts, reaction products and chemical additives. The main parameters of concern in the final effluent into the environment are pH, oil and grease, phenols, sulphide, ammonia-nitrogen and total suspended matter. There is a potential for significant soil and groundwater contamination to have arisen at petroleum refineries.

There is a potential for significant soil and groundwater contamination at petroleum refineries (http://www.ebrd.com/about/policies/enviro/ sectoral/chemical/ refin. pdf).
The following substances are as deleterious substances;

(a) oil and grease;
(b) phenols;
(c) sulphide;
(d) ammonia nitrogen;
(e) total suspended matter; and
(f) any substance capable of altering the pH of liquid effluent or once-through cooling water. (http://www.canlii.org/ca/regu/crc828/sec4.html)

Key sources of such contamination at petroleum refineries are:

1. transfer and distribution points in tankage and process areas, also general
2. loading and unloading areas;
3. land farm areas;
4. tank farms,
5. interceptors;
6. additive compounds;
7. pipeline runs;
8. drainage runs;

9. pump raft/pipe manifold areas;
10. vehicle washing facilities;
11. maintenance workshops;
12. on-site waste treatment facilities, impounding basins, lagoons, especially if unlined.

As an example the effluent of two factories of a petroleum industry called Petroleum 1 for confidentiality purposes are discussed. The chemical effluent analyses of data obtained for the petroleum industry in this study indicated 2 mg per litre of ammonia for Factory 1 and 5 mg per litre for Factory 2. Factory 2 produces the largest quantity of effluent. Should the effluent be disposed of in a river or a freshwater dam, it would contribute to eutrophication. The COD analyses of the effluent indicated values of 31 mg per litre for factory one and 49 mg per litre for Factory 2. These values suggest that the water is being treated prior to discharge and, as a result, the COD would have a minimal impact on the environment. It was also interesting to note that both the Factory 1 and Factory 2 recycle the water used and this contributes to the high conductivity especially in the effluent of Factory 2. Based on the data received, the risk associated with petroleum will be that of the ammonia concentration, which would contribute to eutrophication should the water enter the natural environment.

Table 6-15: Petroleum 1 – Water use and Effluent statistics

	Factory 1	**Factory 2**
River water used (Mm^3)	89.474	29.38
Potable water used (Mm^3)	1.043	4.26
Water recycled (Mm^3)	46.388	50.059
Total liquid effluent (Mm^3)	4.964	16.421
Conductivity of effluent (mS/m)	63	1364
COD of effluent (mg/ℓ)	31	49
Ammonia content of effluent (mg/ℓ)	2	5
Other water supplies (boreholes) (Mm^3)	Not provided	10.528

6.3.8 Pulp, paper and paper product manufacturing

6.3.8.1 Production

The production processes for the various products manufactured by a typical paper and packaging group, are as follows:

Hardwood and softwood kraft pulp: Pulpwood, either hardwood or softwood, is chipped into small pieces and cooked in an aqueous solution of various chemicals to release the wood fibres. The fibres are then drained and dried to produce unbleached pulp, or whitened by bleaching processes prior to drying to form bleached pulp, which has a higher brightness characteristic.

Paper, board and packaging: Paper is produced using various grades of pulp and recycled fibre, together with various chemicals, water and energy, and is pressed and dried through a series of rollers to produce paper and paperboard. Printing and writing papers, specialty papers and tissues are manufactured mainly from bleached pulp, while packaging papers are manufactured mainly from unbleached pulp. Packaging papers are converted through a process of printing, cutting and glueing to make paper sacks and folding boxes. Corrugated board is made by pressing a particular grade of corrugating material, fluting, through rollers to give it a wave like form. This is then used as a spacer, glued between two liners to form corrugated board that is then cut, folded and glued or stitched to make corrugated containers.

6.3.8.2 Effluent risk assessment

Among the procedures involved in pulp and paper manufacturing, bleached kraft pulp processing is especially notorious for its process water and energy consumption. Along with other chemical inputs from the pulping and bleaching processes, industry must deal with a plethora of contaminants that may be present in the pulp and paper effluent.

Common concerns include:

1. Biochemical and chemical oxygen demand (BOD/COD);
2. Levels of total suspended solids (TSS);
3. Presence of filamentous bacteria and fibre in wastewater;
4. Effluent temperature;
5. pH level;
6. Odour, as well as
7. Phosphorous concentration.

Risks associated with pulp, paper and paper product manufacturing are discussed using information regarding the chemical analysis of typical paper industries in Cape Town (**Table 6-16**) Port Elizabeth (**Table 6-17**) East London (**Table 6-18**) and Tshwane (**Table 6-19**). Information was obtained from various paper industries called Paper 1 to 4 for confidentiality purposes. The chemical analysis of effluent from Paper 3 is shown in **Table 6-20**.

Table 6-16: Paper industry effluent data (Cape Town)

Industry type	Volume of effluent per year (kℓ)	COD (mg/ℓ)	pH	EC (mS/m)
Paper 2	400 000	1 461	6	173
Paper 1	350 000	5 898	6	348

Table 6-17: Paper industry effluent data (Port Elizabeth)

PE Main Water Users	Annual Water Consumption (kℓ)	Annual Effluent production (kℓ)
Paper 1	16 304	13 043

Table 6-18 Paper industry effluent data (East London)

East London Main Water Users	Annual Water Consumption (kℓ)	Annual Effluent production (kℓ)
Paper 2: Location 5	10 823	8 229

Table 6-19: Chemical analysis of the paper industry effluent (Tshwane)

Industry type	COD (mg/ℓ)	Ammonia (N) (mg/ℓ)	Nitrite/ Nitrate (N) (mg/ℓ)	Phosphate (P) (mg/ℓ)	pH	EC (mS/m)
Paper recycling	14225	8.7	1.52	4	8	144
Carton recycling and manufacturing	3667	0	3	6	8	105

EC = Electrical conductivity

Table 6-20: Paper 3 Total water use and effluent data

Parameter	2002	2003
Total water consumed for production (non-cooling) (Mm^3/a)	117	114
Total effluent resulting from production (Mm^3/a)	100	98
Total BOD5 (t/a)	118 845	153 381
Total COD (t/a)	488 937	620 172
Total suspended solids (t/a)	13 950	18 460

The effluent generated by pulp and paper mills varies considerably depending on the processes employed. Paper mills without pulping facilities generally produce effluents with a suspended solids and COD/BOD component. At present, major contaminants of concern to the pulp and paper industry are biochemical oxygen demand (BOD) and the amount of total suspended solids present in pulp and paper processing effluents. Due to the large volume of wastewater generation, the majority of pulp and paper mills in South Africa currently utilize primary and secondary wastewater treatment on-site to manage these contaminants. Such treatment technologies commonly include primary clarifiers, settling ponds, sedimentation basins, as well as activated sludge treatment systems and aeration basins.

These systems may also be capable of removing significant amounts of other contaminant parameters such as absorbable organic halides (AOX) and chemical oxygen demand (COD). Tertiary treatment, which usually involves removal of colour present in effluent, isn't yet a prevalent practice. In addition, many technology-based effluent limitation guidelines for the control of toxic releases consist of process changes that substitute chlorine dioxide for elemental chlorine, thus resulting in complete elimination of elemental chlorine in the bleaching process.

Pulp and paper mills have historically been a significant source of dioxin emissions. Most of their emissions are via wastewater discharges. The wood used to produce paper contains lignin, a dark-coloured substance that must be bleached in order to produce white paper. When chlorine is used as the bleaching agent, it reacts with the lignin to produce dioxin, which then appears in the paper products, and in the mill's wastewater and sludge. When dioxin-contaminated wastewater is discharged into bodies of water, dioxin levels can concentrate in the aquatic food chain, pushing dioxin levels in fish to unacceptable levels. In South Africa today no mills bleach with chlorine gas and therefore new dioxin generation has ceased. If there is an unbleached pulp mill attached, salinity of the effluent becomes an issue. If the mill bleaches the pulp, only then do chlorinated organic compounds become an issue. There are only 5 mills that bleach chemical pulp in South Africa. There are still issues relating to the residual effects of past chlorine bleaching at two mills. The two mills in South Africa producing pulp from bagasse do spread the pith from the bagasse back onto land. De-pitching takes place well before pulping and bleaching processes. Some reduction in colour can be achieved in secondary treatment of pulp mill effluents.

The dioxin-contaminated sludge from paper mills, which is mostly land filled, represents one of the biggest dioxin reservoirs. Alternatively, some paper mills burn this sludge or spread it on land. Both of these disposal alternatives can pose significant risks to people and wildlife. In recent years, more mills have started using chlorine dioxide ("elemental chlorine-free") instead of chlorine gas in the bleaching process in order to further reduce dioxin wastewater discharges. Unfortunately very limited data was available for the pulp and paper manufacturing industry in terms of the effluent produced.

The data that was received will now be discussed. The COD values ranged from 700 mg per litre to 21,000 mg per litre. There is no doubt that water with a COD value exceeding 1000 mg per litre will have a negative impact on natural waterways and dams. The major consequence would be the depletion of oxygen in these environments due to the consumption of oxygen by micro-organisms, which are oxidising the organic matter. The BOD values that were given suggest that the organic matter in the effluent was readily biodegradable. This of course would contribute to the depletion of oxygen should these effluents be discharged into rivers and dams without treatment. The pH of the effluent was in the range of six to seven and this does not pose a major threat to the environment. The suspended solids values indicate a very high level of up to 6000 mg per litre in some of the effluents. These values are not surprising given the high COD values for some of the effluents. Should the effluent from pulp and paper manufacturing not be treated it would have a major negative impact on the environment and especially receiving waters.

6.3.9 Tannery

6.3.9.1 Production

Most leather is tanned using chrome-tanning salts. Only a small amount of shoe sole, saddle, and belt leathers are still tanned by the traditional vegetable tanning process that uses vegetable tannins extracted from tree bark as the tanning agent. The following is a brief outline of how chrome tanned leather is made:

The salt-cured (or more often nowadays, fresh or "green") hides are soaked in water in large, slowly turning drums to wash out the salt and return the hide to the same condition as it was on the living animal. After a minimum of four to six hours, the water is drained off and fresh water is added. Lime and sodium sulphide are added and the drum is run intermittently every hour for five minutes for the next fourteen to eighteen hours. This removes the hair and other unwanted protein in the hide and opens up the fibre structure. The following morning the hides are scraped clean of excess fat on a "fleshing machine" and the limed pelts are then loaded into another drum for further processing. Upholstery hides at this stage are also split.

In the drum the hides are firstly washed and then in a fresh float, ammonium sulphate is used to remove excess lime from the pelt. An enzymatic-bating agent is added to further open up the fibre structure and clean the grain and then the hides are washed again with cold water.

A small amount of fresh water is now run into the drum and common salt (sodium chloride) and sodium formate buffer are dissolved in it. Sulphuric acid is pumped into the moving drum through the axle and the drum is run for a further one and a half to three hours. The salt prevents the acid from damaging the hides by preventing swelling. Chrome tanning salt (a green powder) is added and the drum is run for 1-3 hours, after which magnesium oxide is added and the drum is run overnight to an end pH of 3.6-4.0 and an end temperature of about 45 degrees Celsius. The following morning the hides have been tanned and can now be called wet blue. Chrome-tanned (wet blue) leather has a characteristic bluish colour.

After being piled on "horses" or pallets for a day to drain, the hides are "sammed" (i.e. squeezed through a machine like a giant mangle) to remove excess moisture, sorted visually into various grades, then split through a band knife splitting machine and finally shaved to the correct thickness. The drop (flesh) split is trimmed and shaved for either suede split, finish coating or industrial gloving split leather.

The shaved wet blue is now made up into lots for dyeing. Because the chrome tanning process is acidic, the leather is first neutralized with sodium bicarbonate and sodium formate or acetate, after which it is re-tanned with synthetic tanning agents called syntans, resins and natural tannins, which impart the desired properties to the leather being made. The leather is then dyed to the required shade and finally "fat liquored"-natural and synthetic oils are taken up by the leather to replace the natural greases removed in the preceding processes, so that the fibres will be lubricated when the leather is dried.

The leather is again horsed up overnight to drain, set out on a setting machine to remove wrinkles and then dried. Various methods are employed:

- "Corrected Grain" sides are usually paste-dried. They are pasted onto glass or steel plates, which then pass through a drying tunnel.
- Alternatively, they are vacuum-dried by slicking out on a smooth heated stainless steel table and then lowering a head onto the table and removing the moisture by vacuum suction at a temperature well below the boiling point of water.
- "Full Grain" sides are generally toggle-dried – stretched out on frames by means of toggle clips before passing through a drying tunnel.
- Hung up to dry with no stretching.

After drying, the sides are sprayed lightly on the back (flesh) side with water and piled under plastic to condition and even out the moisture content for a few hours. They are then staked, or softened, and the corrected grain sides are then buffed, or sandpapered, to remove, or at least minimize, surface defects. Full grain sides are not buffed, but are left with the natural grain pattern and are therefore made from top quality hides. Before being sent for finishing all leather is again sorted into various grades to ensure that the wet blue sorting was correct.

Finishing of leather may be likened to the paint shop in a motor assembly plant. Here various pigments, resins, binders, lacquers and dyes are applied by curtain-coater, pad, roller-coater and spray machines to give the leather its final colourful, scuff-resistant look and feel.

Leather is often softened after finishing by milling in a milling drum for a few hours. Finally, the area of the sides is measured and the leather is sent to the warehouse for final sorting and packing before dispatching. Automotive and furniture upholstery leather is processed throughout as whole hides, while shoe upper leather is normally processed as sides (a hide is cut down the backbone into two sides).

6.3.9.2 Effluent risk assessment

Water use and effluent data on the tannery industry was obtained from the metropolitan council of Tshwane (**Table 6-22**).

Table 6-21: Characterisation of tannery wastewater

Parameters	**Raw wastewater mg/ℓ**
Total COD	5 094
Soluble COD	2 336
BOD5	1 760
SS	2 229
TKN	358
Org N	223
NH3-N	135
Total Cr (Cr^{+3})	116
Sulphur (S)	51

Total dissolved solids have become a major problem in many counties. For example countries such as South Africa (1350 mg/ℓ of total dissolved solids), Italy (1200 mg/ℓ of chloride, 1000 mg/ℓ of sulphate), India (2100 mg/ℓ of TDS, 1000 mg/ℓ of chloride, 1000 mg/ℓ of sulphate), have set up regulations to limit the concentration of salts effluents after wastewater treatment.

In tannery effluent, this regulation is very difficult to respect. The main reasons are as follows:

1. Most of the high quality raw hides and skins are preserved through a salting process using between 30 to 50% of common salt compared to the weight of raw hide/skin. This sodium chloride remains in the hide/skin as long as there is no washing process undertaken.

2. The drying procedure is limited to warm countries, where salt and energy source is expensive.

3. Fresh processing of hides and skins need a source of raw material constant in quality and quantity.

4. Chilling hides or skins is feasible in countries where energy is cheap and where slaughtering facilities are already equipped with appropriate cooling facilities.

5. Other preservative chemicals are suitable for short-term preservation, but are not yet adapted for the long term.

6. Some sodium chloride is necessary for pickling procedures before tanning.

7. During leather production, various inorganic chemicals are added (sulphate, etc). These chemicals are essential and their replacement is very difficult.

Consideration must be given to reducing to total TDS per kg of hides/skins processed, not only the TDS concentration. Trimming and, where possible, pre-fleshing are generally recommended to reduce the amount of salt added for preservation.

Beside alternative preservation methods, there are a few established technologies to reduce TDS:

- Shaking the hide/skin mechanically or manually.
- Direct recycling of liming
- Organic acids compounds or CO_2 deliming instead of ammonium salts.
- Direct recycling of the pickling float.
- Direct recycling of tanning floats.
- Recycling of supernatant from chrome recovery
- Use of liquid dyes and syntans, etc.
- Use of short float with reduced load of chemicals

TDS up to 20 g/ℓ and chlorides up to 10 g/l do not substantially decrease the efficiency of biological treatment of tannery effluents. High levels of TDS and sodium chloride are present in tannery effluent before wastewater treatment. The TDS concentration can reach 7,000 mg/ℓ and in some cases more than 10,000 mg/ℓ. The less water is used for leather production to higher the TDS concentration. Wastewater treatment eliminates most of the suspended solids, large quantities of dissolved organic chemicals, and also nitrogen but it has hardly any effect on TDS.

Table 6-22: Chemical analysis of the tannery industry effluent (Tshwane)

Industry type	**COD (mg/ℓ)**	**Ammonia (N) (mg/ℓ)**	**Nitrite/ Nitrate (N) (mg/ℓ)**	**Phosphate (P) (mg/ℓ)**	**pH**	**EC (mS/m)**
Cattle tannery	2108	31	<1	8	7	350
Sheep and game tannery	560	2	0	2	7	935

EC = Electrical conductivity

The COD and phosphate values could contribute to a substantial environmental impact in terms of eutrophication and/or oxygen depletion in the receiving water bodies. The tannery effluent typically contains up to 50 mg/l of sulphur and a very high suspended solids concentration of up to 3 000 mg/l. Another constituent that is potentially very harmful to the environment is chrome, with concentrations of up to 132 mg/l. In this survey, the COD value for cattle tannery was 2108 mg/l, the ammonia concentration 31 mg/l and phosphate concentration 8 mg/l (**Table 6-22**). These values were much higher than for sheep and game tannery effluent (**Table 6-22**). Cattle tannery effluent therefore poses a greater risk, should it be disposed of in natural water systems.

6.3.10 Textile manufacturing

6.3.10.1 Production

Textile mill effluents (TMEs) are wastewater discharges from textile mills that are involved in wet processes such as scouring, neutralizing, desizing, mercerizing, carbonizing, fulling, bleaching, dyeing, printing and other wet finishing activities. They are not generated at facilities that conduct only dry processing (carding, spinning, weaving and knitting), laundering or manufacture of synthetic fibres through chemical processes. In the context of this report, TMEs do not include waste streams such as air emissions or solid waste. (http://www.c2p2online.com/documents/bmp-textiles.pdf)

TMEs contain a wide range of chemicals and are known to have a range of pH, temperature, colour and oxygen demand characteristics. The environmental risk of nonylphenol and its ethoxylates in TMEs has been determined. (http://www.c2p2online.com/documents/bmp-textiles.pdf)

Estimated Toxic Exposure Values based on nonylphenol toxic equivalency quotients (EEVTEQ) for nonylphenol (NP) and nonylphenol ethoxylates (NPEs) in untreated TMEs exceeded the chronic toxicity threshold for invertebrates in 90% of samples and the chronic toxicity threshold for fish in 86% of samples. Eighty-three percent of untreated samples had NP and NPE EEVTEQs falling within the range of acute toxicity to fish, invertebrates and algae. All five primary-treated TME samples had NP and NPE EEVTEQs falling within the range of acute toxicity to fish and invertebrates and exceeding chronic toxicity benchmarks for those organisms.

Assessments of these substances found that untreated or inadequately treated NP, NPEs, and TMEs are harmful to the environment, especially aquatic organisms. Furthermore, degradation products of NPEs are often more harmful and more persistent than the parent compounds.

A key factor in water usage in dyeing, scouring, bleaching and other textile finishing processes is the “liquor ratio” – the volume of liquor required in the process per kilogram of fibre. Dyeing plants have been developed which operate with progressively lower liquor ratios to reduce water usage. Care should be taken to investigate the overall environmental impact of some of these processes before a decision is made to adopt them.

Exhaust dyeing can achieve high levels of dye fixation to the fibre and may produce significantly lower levels of dye waste. Simple effluent volume reduction may result in reduced effluent disposal charges, but the effect of volume reduction may simply be to concentrate contaminants. This could require contaminant minimisation or treatment to meet trade waste acceptance standards or to reduce environmental impacts in cases of discharges to surface waters.

Based on the available data, it is concluded that textile mill effluents are entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity.

It is recommended that options to reduce environmental risk be examined on a site-specific basis. In addition, pollution prevention opportunities for the management of TMEs should be identified and evaluated, with particular attention to the use and release of NP and its ethoxylates. Depending on whether tanneries have their wastewater treated at municipal wastewater treatment plants, it is recommended that discussions with the appropriate authorities (municipal and/or provincial) be undertaken to address the risks.

6.3.10.2 Effluent risk assessment

It was interesting to note that the textile industry is the second largest producer of effluent in the Cape Town metropolitan area, third largest in the Durban and East London metropolitan areas and also features as the third largest effluent producer in Port Elizabeth. The effluent from textile facilities indicates COD values ranging from 537 to 9553 mg per litre (**Table 6-24** and **Table 6-24**). This would have a major negative impact on the natural water environment, leading to oxygen depletion. The phosphate concentration ranges from 1 to 39 mg/l. This would contribute significantly to eutrophication should the water be discharged into the environment. The pH of the effluent varies between 5 and 12 with the majority of effluents having a pH above eight.

Table 6-23: Textile industry effluent data (Cape Town)

Industry type	COD (mg/ℓ)	pH	EC (mS/m)	Cl (mg/ℓ)
Textiles 1	9553	5	80	NP
Textiles 2	1152	7	77	NP
Textiles (Rotex)	991	11	468	961
Cotton Mill	2016	12	1517	NP

NA = Not Available
EC = Electrical Conductivity

Table 6-24: Chemical analysis of the textile industry effluent (Tshwane)

Industry type	COD (mg/ℓ)	Ammonia (N) (mg/l)	Nitrite/Nitrate (N) (mg/ℓ)	Phosphate (P) (mg/ℓ)	pH	EC (mS/m)
Felt production	3552	0	0	39	7	30
Textile 1	1623	<1	<1	6	8	228
Textile 2	1347	19	<1	1	6	129
Textile 3	537	46	0	36	8	95

EC = Electrical conductivity

6.3.11 Washers/Laundry

6.3.11.1 Production

Not all dry cleaning and laundry facilities produce hazardous waste. Potential hazardous wastes generated by dry cleaning and laundry plants are primarily solvents and these include the following:
Perchloroethylene, otherwise known as perc, PCE, or tetrachloroethylene.

Perchloroethylene plants potentially produce the following three types of hazardous wastes:

- Still residues from solvent distillation (the entire weight)
- Spent filter cartridges (total weight of the caridge and remaining solvent after draining)
- Cooked powder residue (the total weight of drained powder residues from diatomaceous or other powder filter systems after heating to remove excess solvent)
- Valclene, also known as fluorocarbon 113 or trichlorotrifluoroethane.

Valclene plants potentially produce the following two types of hazardous wastes:

- Still residues from solvent distillation (the entire weight)
- Spent filter cartridges (total weight of the cartridge and remaining solvent after draining)
- Petroleum solvents, such as Stoddard, quick dry, low-odour, and other solvents. Petroleum solvent plants potentially produce only one type of hazardous waste:
- Still residues from solvent distillation (the entire weight)

6.3.11.2 Effluent risk assessment

Table 6-25: Chemical analysis of the laundry industry effluent (Tshwane)

Industry type	COD (mg/ℓ)	Ammonia (N) (mg/ℓ)	Nitrite/ Nitrate (N) (mg/ℓ)	Phosphate (P) (mg/ℓ)	pH	EC (mS/m)
Laundry	330	<1	3	35	9	99
Laundry	1390	<1	0	21	9	512

EC = Electrical conductivity

The effluent analyses from the laundry industry indicated their high concentration of phosphate, up to 35 mg per litre and some nitrate (3 mg per litre and less). Should the effluent from the laundry industry be discarded of in a natural system, it would make a contribution to eutrophication. Another risk associated with laundry effluent is the high pH (above 9) and in some cases also a high COD concentration of up to 1300 mg per litre. Fortunately most of the laundry effluents end up in the municipal sewerage system and is treated in the activated sludge process. There are nevertheless hotels, which do a lot of laundry that are not located in cities and should the effluent from these hotels be discarded in the natural environment, it would have a negative impact on the receiving water body.

6.4 FOOD AND BEVERAGE

6.4.1 Abattoir industry

6.4.1.1 Production

Official numbers of registered abattoirs at the Red Meat Abattoir Association (RMAA) are shown in (**Table 6-26**).

Table 6-26 Overview of the SA abattoir industry

Class	Slaughter units	Number of abattoirs	Estimated slaughtering per class (%)
A	> 100	33	40
B	50-100	38	20
C	15-50	38	15
D	8-15	70	15
E	< 8	162	10

In most parts of Southern Africa, cattle farming constitutes a significant proportion of agricultural activities and contribute largely to the sustenance of rural populations for agricultural purposes. The estimated total number of cattle, sheep and pigs slaughtered annually in South Africa is given in (**Table 6-27**).

Table 6-27: The annual slaughter of cattle, sheep and pigs at registered abattoirs in S.A.

Animal	Number slaughtered annually
Cattle	1.95 million
Sheep	4.50 million
Pigs	2.00 million

FEEDLOTS

The feedlot industry produces approximately 70 to 80% of beef in the formal sector in South Africa. At any point in time, it is estimated that this sub sector has a standing capacity of 420 000 head of cattle. This industry has a potential throughput of 1.512 million animals annually. Animals normally enter the feedlot system at a mass of between 200 and 220kg and remain in the feedlot for approximately 100 days. During the time in the feedlot, the animal adds approximately 100kg to its original weight, which realises a carcass weighing between 320 to 325kg. The amount of beef produced in feedlots amounts to 340 000 tonnes per year and the total amount of feed used by the feedlot industry amounts to approximately 1.5 million tonnes.

SLAUGHTERING AND DRESSING

Meat goes through many operations before it hangs dressed in cold stores. The animals are stunned before they are slaughtered and dressed. After slaughtering the carcass is suspended from an overhead rail for the dressing operation, in which the hide and the internal organs are removed. Further along the line various trimming procedures are performed. By the time it reaches the end of the chain the carcass is clean and ready for chilling and classification.

6.4.1.2 Effluent risk assessment

Water is used for the watering and washing of livestock, the washing of trucks, washing of carcasses and by- products and for cleaning and sterilizing equipment and process areas. Water consumption can vary depending on the size of the plant, the age and type of processing, the level of automation and cleaning practices.

Some key strategies for reducing water consumption are listed below and the use of these techniques would represent best practice for the industry:

- Undertaking dry cleaning of trucks prior to washing with water
- Using automatically operated scalding chambers rather that scalding tanks for the de-hairing of pigs
- Using offal transport systems that avoid or minimize the use of water
- Using dry dumping techniques for the processing of cattle paunches and pig stomachs that avoid or minimize the use of water instead of wet dumping techniques
- Reusing final rinse waters from paunch and casing washing for other non- critical cleaning steps in the casings department
- Reusing wastewaters from the slaughter floor, carcass washing, viscera tables and hand wash basins for the washing of inedible products
- Reusing cooling water
- Reusing the final rinse from cleaning operations for the initial rinse on the following day
- Using dry cleaning techniques to pre- clean process areas and floors before washing with water
- Using high pressure rather than high volume for cleaning surfaces
- Using automatic control systems to operate the flow of water in hand-wash stations and knife sterilizers

Most of water consumed at abattoirs ultimately becomes effluent. Abattoir effluent contains high levels of organic matter due to the presence of manure, blood and fat. It can also contain high levels of salt, phosphates and nitrates. The most significant contributor of the organic load is blood followed by fat. Blood is also the major contributor to the nitrogen content of the effluent stream. Salt and phosphorus originate from the presence of manure and stomach contents in the effluent. At those plants where rendering occurs, the effluent from rendering typically represents the single most significant source of pollutant load in abattoir effluent.

The wastewater quality from red meat abattoirs could be broadly summarized as follows:
pH 5 to 6; COD 784 to 3450 mg/l; suspended solids 654 to 1607 mg/l; Chlorides, 92 to 184 mg/l (**Table 6-28**).

Table 6-28: An extract of the chemical analysis of the abattoir industry effluent (Durban)

Date	Chloride mg/ℓ	COD mg/ℓ	Colour Hazen units	Conductivity mS/m	pH	Settlable solids ml/ℓ	Sodium mg/ℓ	Sulfate mg/ℓ	Suspended solids mg/l
21/01/2004	156	2 915	137	130	6	34	107	28	1 024
24/02/2004	127	2 635	1 060	104	5	0	78	39	818
30/03/2004	138	865	1 575	88	6	11	240	24	856
29/04/2004	92	784	660	64	6	30	62	36	858
22/06/2004	143	2 625	1 575	107	6	21	105	29	654
27/07/2004	172	3 040	695	122	6	42	138	25	1 090
27/08/2004	150	960	542	120	6	64	78	33	1 225
29/09/2004	184	3 450	1 015	130	6	65	114	62	1 816
28/10/2004	142	2 980	680	122	6	35	170	74	1 000
2004/03/12	140	1 320	527	86	5	80	132	13	1 607
19/01/2005	143	2 475	1 400	102	6	42	69	64	1 372

As already stated a strategic approach towards water and waste management at abattoirs in accordance with DWAF's water conservation, waste minimization and progressive waste treatment philosophies (commencing with good housekeeping and low-cost technology and sequentially proceeding to sophisticated recovery and treatment technologies) should almost routinely be followed.

Water use licenses and disposal site permits should make provision for conditions which will force abattoirs to incrementally progress towards predetermined water quality and waste management objectives within specified time frames. In the interim (until this document is fully finalized) general areas of waste management improvement should include minimization of waste generation at source (including maximizing the recovery of useful materials), seriously curbing the practice of washing solids to drain (which transfers waste solids to the liquid medium) and promoting research into cleaner technology and recovery of higher value products from the waste stream.

6.4.2 Brewery

6.4.2.1 Production

Brewery industries produce fermented beverages made from grain. The main ingredient is barley, however, maize wheat and other types of grain may be used (World Bank Group, 1998). There are three main steps involved in the production of alcoholic beverages. Each stage consumes large volumes of water.

MALT PRODUCTION
This is the first stage in beer production where barley is soaked in cold water for 45 to 72 hours. It involves the germination of grain to produce enzymes that facilitate the production process. The sprouted barley (malt) is dried to give the beer its characteristic aroma. The colour of the beverage is determined by the heat intensity used for the drying process (malt can be toasted from light tan to dark brown).

WORT PRODUCTION

This involves mashing and cooking the malt. The malted grain is crushed and the resultant powder mixed with warm water. Supplementary grains are added to the mixture. If raw grain is used as opposed to cereals, the grain has to be pre-cooked (boiled in water). The temperature of the mash is raised from 38˚C to 77˚C. The mixture is left undisturbed, allowing the malt to settle to the bottom of the production tub forming a filter bed. The liquor, which runs through the filter, is now called wort. Hot water is run through the filter to rinse out any remaining wort.

BEER PRODUCTION

The final stages of production include fermentation and cellaring. Yeast is added to the wort to begin fermentation. Fermentation takes a number of days depending on the type of beer brewed. Once this process is completed, the yeast is extracted and the beer is stored in cellars. The beer is stored for a period ranging between 3 to 12 weeks. After this time, it is placed in pressure tanks for final fermenting which produces carbon dioxide gas (giving the beverage its characteristic foam). The beer is finally filtered and packaged in bottles or cans.

6.4.2.2 Effluent risk assessment

Breweries produce brewery wastewater that can be characterised into three different groups, which are:

1. trade wastewater from production;
2. sanitary wastewater from amenities; and
3. storm water.

The sanitary wastewater produced on site contributes only a minimal loading whether measured as organic material or as flow. The amount of trade wastewater produced is dependent on the extent of production and the efficiency of water usage. SAB on average produces 36,000 kl of trade waste per annum. Peak flows occur in the brew house and the beer processing area, as they are associated with cleaning operations. In the packaging area peak flows occur when the line is closed down and the bottle washers and tunnel pasteurizers are emptied. Peaks can also occur in the water treatment area during the backwash of filters. The concentration of organic material is dependent on the waste water-to-beer ratio and the discharge of organic material as wastewater. It is present in the form of soluble material. The concentration of organic material is usually measured in COD (Chemical Oxygen Demand) or BOD (Biological Oxygen Demand). The typical discharge of organic material from a brewery varies but it is normally in the range of 0.6-1.8kg BOD/hl beer. The trade wastewater stream produced is normally low in non-biodegradable components. The trade wastewater generally has a COD/BOD ratio of 1.5-1.7 indicating that it is easily degradable. A summary of the general characteristics of brewery trade wastewater is presented in **Table 6-29**.

Table 6-29: Characteristics of Brewery Trade Wastewater

Characteristics	**Amount**
Water-to-beer ratio	4-10 hℓ water/hℓ beer
Waste water-to-beer ratio	1.3-2 hℓ/hℓ lower than the water-to-beer ratio
BOD	0.6-1.8 kg BOD/hℓ beer
Suspended solids	0.2-0.4 kg SS/hℓ beer
COD/BOD	1.5-1.7
Nitrogen	30-100 g/m^3 waste water
Phosphorous	30-100 g/m^3 waste water
Heavy metal concentration	Very low

Brewery spent grains (BSG) and yeast are by-products from beer making. They are commonly used as livestock feeds but their usage is often constrained by transportation costs and the freshness of the materials. Other uses may need special processing technology and is dependent on a market for extracted products. Both BSG and yeast will degrade within 24 hours and emit odour that animals may reject. Thus small farmers find it uneconomical to collect small amounts of spent grains daily if the brewery is more than 2-3 hours away. Drying of BSG and yeast (separately or mixed) is the solution if a cheap source of energy like solar energy or waste heat is available. It is not uncommon that BSG is land filled. In some developed countries where landfill costs are very high, BSG may be dried and sold as animal feeds.

Depending on the state of technology used by the brewery, the BOD of brewery wastewater is between 1.8-1.2 kg per hl of beer produced. Where glass bottles are used, washing bottles require about 0.5-0.25 kg caustic soda is used for every hectolitre of bottled beer produced. The accidental discharge of wastewater that has a very high pH will damage and kill most vegetative plant life in the receiving waters.

“The amount of water used [and hence effluent produced] for a unit of finished beer will depend on factors such as packaging and pasteurisation, technology employed, the age of the plant and internal housekeeping” (http://www. sabmiller.com). In modern breweries, the volume of water used ranges between 3.5 to 7 hectolitres per hectolitre of beverage produced. In a ‘good practice’ brewery the greater percentage of total water consumption is seen in the brew house and cellars (48%) while the least (1%) is used for domestic purposes in the day-to-day functioning of the industry. Water use is divided into two categories: the production of beer (accounts for 20-30% of the total consumption) and the auxiliary operations (cleaning and cooling). Reuse of water in this industry is not usually a management option, as it cannot be used at any point where the water comes in contact with the product. It may however be reused for domestic purposes such as cleaning of floors in the plant. The water consumption in a South African brewery (values given as hectolitres of water used per hectolitre of beverage produced) is given below:

Table 6-30: Chemical analysis of the brewery industry effluent (Tshwane)

Industry type	COD (mg/ℓ)	Ammonia (N) (mg/ℓ)	Nitrite/ Nitrate (N) (mg/ℓ)	Phosphate (P) (mg/ℓ)	pH	EC (mS/m)
Brewery	1 446	29	< 1	9	7	294
Sorghum brewery	2 156	< 1	< 1	54	4	81

EC = Electrical conductivity

Breweries can achieve an effluent discharge of 3-5 m^3/m^3 of sold beer (exclusive of cooling waters). Untreated effluents typically contain suspended solids in the range 10-60 milligrams per litre (mg/ℓ), biochemical oxygen demand (BOD) in the range 1,000-1,500 mg/ℓ, chemical oxygen demand (COD) in the range 1,800-3,000 mg/ℓ, and nitrogen in the range 30-100 mg/ℓ. Phosphorus can also be present at concentrations of the order of 10-30 mg/ℓ. Effluents from individual process steps are variable. For example, bottle washing produces a large volume of effluent that, however, contains only a minor part of the total organic discharged from the brewery. Effluents from fermentation and filtering are high in organics and BOD but low in volume, accounting for about 3% of total wastewater volume but 97% of BOD. Effluent pH averages about 7 for the combined effluent but can fluctuate from 3 to 12 depending on the use of acid and alkaline cleaning agents. Effluent temperatures average about 30°C.

Solid wastes for disposal include grit, weed seed, and grain of less than 2.2 millimetres in diameter, removed when grain is cleaned; spent grain and yeast; spent hops; broken bottles or bottles that cannot be recycled to the process; and cardboard and other solid wastes associated with the process, such as kieselguhr (diatomaceous earth used for clarifying). Breweries do not discharge air pollutants, other than some odours.

Effective water quality and quantity management involves the reduction in volume of effluents. After determining the effluent quality and quantity parameters, a decision can be made as to whether the wastewater should/can be reduced. In this way waste generation is avoided. As with any other industrial activity, waste generation is however inevitable. The quality of the wastewater generated determines whether re-use is a management option and what specific uses the effluent can be put to. The following figure gives a comparison between the quality of typical untreated effluent and sector guidelines (levels acceptable to the World Bank Group). The following statistical graphics give a representation of the brewery water consumption and effluent production.

Figure 6-1: Ratio of beer produced to wastewater discharged

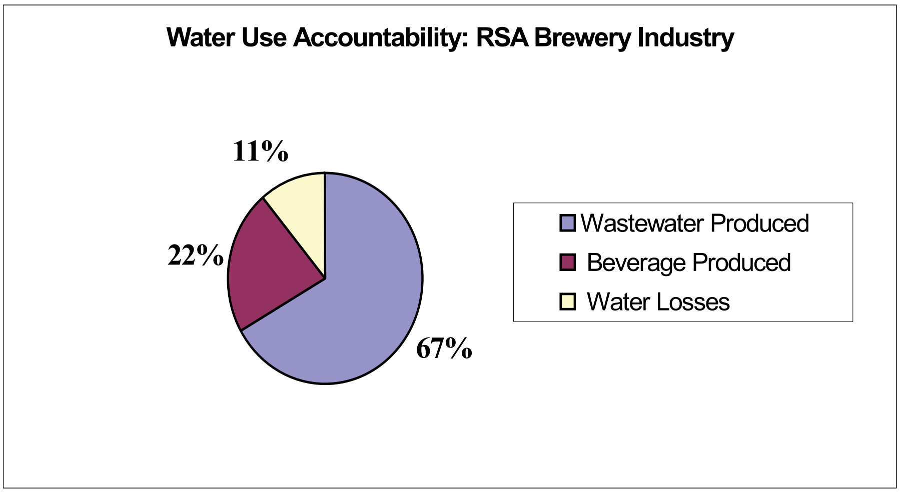
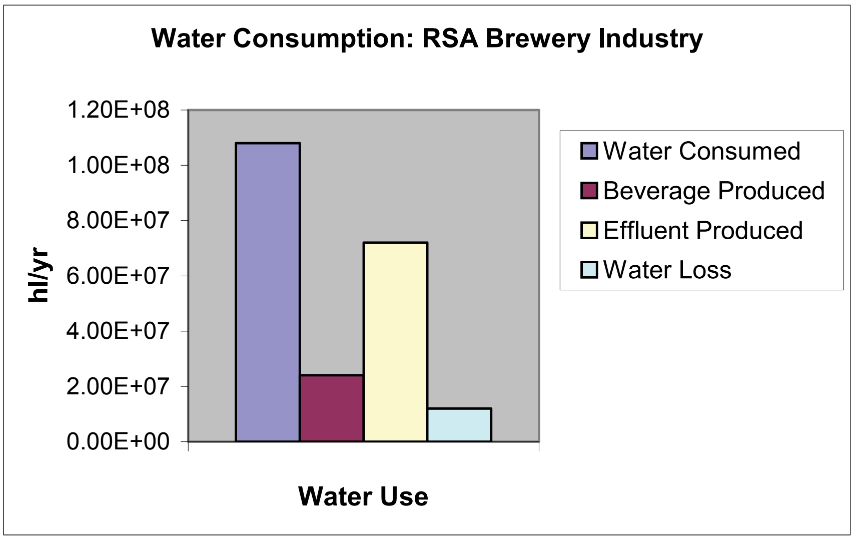


Figure 6-2: Ratio of water use allocation to net water consumed in the brewery industry



In most of the plants, preliminary treatment is conducted on site to reduce COD and TDS, as well as to regulate pH and temperature. This treatment is in the form of anaerobic and aerobic digestion. The treated effluent is then piped to municipal plants for further purification. The effluents produced do not have immediate toxic characteristics. Most COD load results from beer, yeast and malt grain spillage. The greater volume of wastewater is from the various cleaning processes within the brewery plants. This includes cleaning of reusable packaging bottles, reusable crates and rinsing of filled bottles. All vessels used in the brewing process are also cleaned out once emptied.

As was already indicated breweries made a significant contribution in terms of volume of effluent produced in the metropolitan areas where they are present. The COD values ranged between 250 mg per litre and 3000 mg per litre. Without treatment this would have a negative impact on the environment as soon as these values exceed 1000 mg per litre, since it would lead to oxygen depletion as previously discussed. The wastewater also contains a significant concentration of phosphorus ranging between 10 and 30 mg per litre and also significant concentrations of nitrogen. Both of these elements contributed to eutrophication in the natural water environment. Brewery effluent is therefore rich in nutrients required by micro-organisms and very often essential for the proper functioning of activated sludge systems where these are used for treating municipal effluent. The dilemma here is that the breweries are charged for the effluent that is discharged into the sewer system. Consequently many of the breweries have started to treat their effluent to reduce the cost and also to recycle treated water inside the factory for cleaning purposes. In some cases this has had a negative impact on the efficiency of activated sludge systems.

6.4.3 Canning

6.4.3.1 Production

The primary objective of food processing is the preservation of perishable foods in a stable form that can be stored and shipped to distant markets during all months of the year. Processing also can change foods into new or more usable forms and make foods more convenient to prepare.

The goal of the canning process is to destroy any micro-organisms in the food and prevent recontamination by micro-organisms. Heat is the most common agent used to destroy micro-organisms. Removal of oxygen can be used in conjunction with other methods to prevent the growth of oxygen-requiring micro-organisms.

In the conventional canning of fruits and vegetables, there are basic process steps that are similar for both types of products. However, there is a great diversity among all plants and even those plants processing the same commodity. The differences include the inclusion of certain operations for some fruits or vegetables, the sequence of the process steps used in the operations, and the cooking or blanching steps. Production of fruit or vegetable juices occurs by a different sequence of operations and there is a wide diversity among these plants. Typical canned products include beans (cut and whole), beets, carrots, corn, peas, spinach, tomatoes, apples, peaches, pineapple, pears, apricots, and cranberries. Typical juices are orange, pineapple, grapefruit, tomato, and cranberry.

6.4.3.2 Effluent risk assessment

Canning involves a high volume of water-use for washing and food processing purposes. Water quality is a critical issue in this regard as any contamination in the water source has the potential to be passed into the canned product. Attention should therefore be given to the purity of the water source and/or type of water treatment applied. The results of water analysis should be compared to drinking water standards for an indication of suitability. The high volume of water used is also likely to lead to correspondingly high wastewater treatment requirements, unless water recycling is being applied. For fruit and vegetable canning for example, water use can range from 2.5 to 6.0 m^3/t product.

Table 6-31: Chemical analysis of canning industry effluent (Tshwane)

Industry type	**COD (mg/ℓ)**	**Ammonia (N) (mg/ℓ)**	**Phosphate (P) mg/ℓ)**	**pH**	**EC (mS/m)**
Drinking cans	2 045	13	29	9	279

EC = Electrical conductivity

Wastewater from the canning of meat-based foods will contain oil and grease; a high level of COD suspended solids, cleansing agents as indicated by the alkaline pH salt and bacteria. Facilities using automated canning lines will discharge less water and wastes from this source.

Wastewater from fruit and vegetable canning will contain high organic loads, cleansing and blanching agents, salt and suspended solids such as fibres and soil particles. BOD and chemical oxygen demand (COD) of wastewaters is typically high. In addition, pesticides may appear in wastewater after the cleaning of fruit and vegetables. Wastewaters such as these should be minimized and where this is not possible, should be treated to reduce organic loading before discharge to receiving waters.

Unfortunately, limited data was obtained for the fruit and vegetable canning industry. The latter could be a follow-up project.

6.4.4 Cold drinks

6.4.4.1 Production

Raw input water from the local water service provider is received in piping, which enters bulk-holding tanks for additional microbiological, chemical and physical processing. The water is checked before and after treatment against standards for quality. The water purification process includes a multi-barrier treatment:

Production activities that contribute to effluent production include:

- Process equipment cleaning and sanitizing
- Container preparation
- Bottle rinsing
- Fill-line flushing

6.4.4.2 Effluent risk assessment

Grey-water systems are also utilised within operations for cleaning where the water quality is of lesser importance (e.g., washing floors, crates, etc)

Incident, preventive and corrective action systems are in place to identify non-conformances to mitigate and prevent water pollution. An example of Cold drink 1’s proactive management of their waste-water systems is that they have constructed a water treatment plant at one of their manufacturing sites.

The best practicable environmental options are selected where possible in recognition of the water scarcity in sub-Saharan Africa Cold drink 1’s operations are certified to the ISO 14001:1996. Information regarding typical effluent production and effluent chemical constituency of the cold beverage industry was obtained from the metropolitan council of Cape Town. This data is given below.

The COD and pH (range 6-10) industry for the cold beverage industry effluent from Cape Town suggests that no effluent treatment is done and discharge into natural water systems will have a negative impact. However, it is assumed that the effluent is discharged into the sewer system for treatment by the municipality and hence the risk is minimized.

Table 6-32: Cold beverage industry effluent data

Region	Industry type	COD (mg/ℓ)	pH	EC (mS/m)
Cape Town	Cold drinks	2 403	8	62
	Food – cold drinks	1 698	10	76
	Food – cold drinks	2 530	7	31
	Fruit juices	17 571	6	176
Tshwane	Cold drink	396	11	490

EC = Electrical conductivity

6.4.5 Dairy

6.4.5.1 Production

A typical cheese industry processes ± 300 000-350 000 litres of milk per day, into different kinds of cheese. Milk is pumped out of the milking tanks where it is received and washed. The wash action (cleaning-in-place, "CIP") consists out of a swill with cold water which goes to the drain, a soda wash which is recycled, a sour wash which is recycled and a final swill which also goes to the drain. The milk is pumped into silos of 70 000 litres which is washed as mentioned above as soon as the silos are emptied. All the milk that is received on a day is processed the following day. From the silos the milk is pumped through a pasteurizer (plate pack) and a cream segregator (standardising the milk) to the cheese barrels. Cheese is continuously pumped through for 14-16 hours where after the pipe lines etc. are washed as mentioned above.

There are five cheese barrels of 15 000 litres each and each is used randomly about four times a day. Between uses the barrels are given a short wash consisting of a quick swill (2 minutes) a soda wash and another swill, the swills go to the drain and the soda is recycled. At the end of the day all the cheese barrels and downstream equipment are washed thoroughly and in a certain order. This takes about nine hours, thus enabling production for seven days a week. The cream that is released during standardising is cooled down through a plate pack and is then pumped into a silo, which is washed every second day. The whey that is released through the cheese making process is kept in buffer silos and is continuously evaporated. The evaporation process uses the most steam and is also washed daily. This is also relevant for the whey concentrate silos.

6.4.5.2 Effluent risk assessment

Currently about 15 000-19 000 kilolitres of water is used per month by Diary 1. No water is used in the products; all is used in the wash actions and for the generation of steam and ice water. The cleaning of vessels, equipment & machinery is crucial with regards to plant hygiene & food safety. This integral operation consumes large quantities of water. Apart from this, water is used as an ingredient in the production of juices, for sanitary purposes as well as for washing of vehicles.

Effluent is generated from most steps in the process and is generally milk or milk products diluted in cleaning wastewaters, together with detergents, sanitizers, lubricants, and chemicals from boiler and water treatment processes. They are characterised by a relatively high organic concentration. All dairy plants exhibit fluctuations in flow and strength of effluents throughout a production day depending on the processing and cleaning operations taking place.

Best practice for water consumption in market milk processes is reported to be 0.8-1.0 litre water / kg of milk (UNEP, 1997a). Typical COD concentrations range from 180-23,000 mg/ℓ. Low values are associated with milk-receiving operations and high values reflect the presence of whey from the production of cheese, with a typical value being 4,000 mg/ℓ. Total COD load in effluent has been estimated to be approximately 8.4 kg / m^3 milk intake. The COD of whole milk is 210,000 mg/ℓ, and thus a rate of 8.4 kg /m^3 milk implies that 4% of the milk solids received are wasted, which is not uncommon (Barnes et al., 1984).

Optimising cleaning-in-place (CIP) processes and batch scheduling can provide significant Cleaner Production gains. Short production runs have an inherently higher wastage, therefore reducing the number of changeovers through better scheduling will minimise losses of product.

The utilisation of cheese whey is has been a significant problem for the industry. Whey is the liquid remaining after the recovery of the curds, which are formed by the action of enzymes on milk. It comprises 80-90% of the total volume of milk entering the process and contains more than half the solids present in the original whole milk, including 20% of the protein and most of the lactose (Lyons et al., 1989). It has a very high organic content with a COD of approximately 60,000 mg/l (Morr, 1992). There are opportunities to develop value-added by-products from whey such as whey concentrates, protein and carbohydrate extracts.

As for many other food processing operations, the main environmental impacts associated with all dairy-processing activities are the high consumption of water, the discharge of effluent with high organic loads and the consumption of energy. Noise, odour and solid wastes may also be concerns for some plants. Dairy processing characteristically requires very large quantities of fresh water. Water is used primarily for cleaning process equipment and work areas to maintain hygiene standards. The dominant environmental problem caused by dairy processing is the discharge of large quantities of liquid effluent (http://www.agrifood-forum.net/ publications/ guide/ d_chp2.pdf).

Dairy processing effluents generally exhibit the following properties:

1. high organic load due to the presence of milk components;
2. fluctuations in pH due to the presence of caustic and acidic cleaning agents and other chemicals;
3. high levels of nitrogen and phosphorus;
4. fluctuations in temperature.

If whey from the cheese-making process is not used as a by-product and discharged along with other wastewaters, the organic load of the resulting effluent is further increased, exacerbating the environmental problems that can result. In order to understand the environmental impact of dairy processing effluent, it is useful to briefly consider the nature of milk.

For plants located near urban areas, effluent is often discharged to municipal sewage treatment systems. For some municipalities, the effluent from local dairy processing plants can represent a significant load on sewage treatment plants. In extreme cases, the organic load of waste milk solids entering a sewage system may well exceed that of the township's domestic waste, overloading the system. In rural areas, dairy-processing effluent may also be irrigated to land. If not managed correctly, dissolved salts contained in the effluent can adversely affect soil structure and cause salinity. Contaminants in the effluent can also leach into underlying groundwater and affect its quality. In some locations, effluent may be discharged directly into water bodies. However this is generally discouraged as it can have a very negative impact on water quality due to the high levels of organic matter and resultant depletion of oxygen levels.

As with most food processing operations, water is used extensively for cleaning and sanitising plant and equipment to maintain food hygiene standards. Due to the higher costs of water and effluent disposal that have now been imposed in some countries to reflect environmental costs, considerable reduction in water consumption has been achieved over the past few decades in the dairy processing industry.

At modern dairy processing plants, a water consumption rate of 1.3-2.5 litres water/kg of milk intake is typical, however 0.8-1.0 litres water/kg of milk intake is possible (Bylund, 1995). To achieve such low consumption requires not only advanced equipment, but also very good housekeeping and awareness among both employees and management.

Table 6-33: An extract of chemical analysis for dairy industry effluent (Durban)

Date	COD mg/ℓ	EC mS/m	Vegetable oils mg/ℓ	pH
2004/10/02	7 790	209	8.7	11
2004/09/03	3 075	204	172	11
20/04/2004	3 015	192	50	10
2004/11/05	1 920	115	51	8
28/07/2004	1 360	179	69	11
2004/10/08	2 025	147	43	10
21/09/2004	6 200	136	166	5
2004/09/11	3 150	96	300	10
13/01/2005	1 411	125	23	10

EC = Electrical conductivity

Table 6-34: An extract of chemical analysis for dairy industry effluent (Cape Town)

Industry type	COD (mg/ℓ)	pH	EC (mS/m)
Dairy products	2 821	6	111
Food Dairy products	2 136	10	321

COD = Chemical oxygen demand
EC = Electrical conductivity

Table 6-35: An extract of chemical analysis for dairy industry effluent (Tshwane)

Industry type	COD (mg/ℓ)	Ammonia (N) (mg/ℓ)	Nitrite/ Nitrate (N) (mg/ℓ)	Phosphate (P) (mg/ℓ)	pH	EC (mS/m)
Ice Cream	7 238	3	2	43	6	61
Dairy 1	25 008	9	< 1	41	6	82
Dairy 2	583	3	61	24	8	37
Dairy 3	4878	6	2	80	6	101
Coffee creamer	7 985	< 1	< 1	67	4	65

EC = Electrical conductivity

The pH of the dairy effluents in this survey ranged between 5.1 and 11.6. This fluctuation was ascribed to the time of sampling. For example, the pH of the effluent during an alkaline wash cycle would be very alkaline and during an acid rinse as part of the clearing in process, acid. The phosphate concentration was high as indicated in the Tshwane dairy effluent data.

6.4.6 Edible oil

6.4.6.1 Production

The edible oil industry in South Africa utilises only about 65% of its total capacity. The amount of oil that is produced in the country depends on the climatic conditions (Steffen et al., 1989). South Africa is a dry country with only 8.6% of the rainfall available as surface water. The country has a very low average rainfall of 475 mm/a compared to the rest of the world, estimated just over half of the world average of 860 mm/a (Davies and Day, 1998). Droughts are a constant threat to the country's economic growth and social development (Bosch and Cloete, 1993; Steyl, 1999). Good rains lead to good maize, groundnut and sunflower crops, which will result in good oil seed production (Steffen et al., 1989).

The total quantity of oil refined in South Africa has remained relatively constant over the years, at approximately 250 000 t/a (Steffen et al., 1989). 253 315 and 245 222 t/a were produced in 1998 and 1999 respectively (CSS, 2000). Shortages of edible oil are supplemented in the form of unrefined oil imports, which are refined and packaged by local oil producers. Crude sunflower oil accounts for the bulk of imports. During 1995, imports of edible oils and fats totalled R1 billion and exports totalled R188 billion (ITC, 1997).

The edible oil industry as a whole uses vast quantities of water and produces a wide range of pollutants. The edible oil industry consumes about 1.75 x 106 m^3/a of water, which is about 0.11% of the total industrial water use (Steffen et al., 1989; DWAF, 2000). The water is used as a solvent, a coolant, a dust-settler, a cleanser and even as a means of transport

Although the production can vary according to the season (253 315 and 245 222 t/a were produced in 1998 and 1999 respectively – CSS, 2000), the total quantity of oil refined in South Africa has remained relatively constant over the years, at approximately 250 000 t/a (Steffen et al., 1989).

6.4.6.2 Effluent risk assessment

A typical, oil processing plant discharges approximately 35% of the incoming water to sewer, which varies considerably by quality over a 24 hour period. The largest volume and load of the effluent discharged by an edible oil plant arises from the refining operations. The type of method applied for oil processing has a strong bearing on the quantity and quality of effluent produced. Typically about 80% of the effluent volume is attributed to the refinery (Steffen et al., 1989).

Pollution of water by the edible oil industry occurs on every level of production (Sutton, 1994). The main types of pollutants in edible oil plant effluents are fats, oil and grease (FOG), sodium, sulphates and phosphates (Steffen et al., 1989; Adam and Marjanovic, 1996; Hwu, 1998; Khan and Akthar, 1998 WBG, 1989). Gums (phosphatides, sugars, resins and proteinaceous materials) produced during the degumming process may be separated into hydrated and non-hydrated types (Hui, 1996). Pre-treatment of high FFA oils such as maize and sunflower prior to physical refining, comprises of the addition of phosphoric or citric acid. This is done during the degumming process to remove non-hydrated gums (Steffen et al., 1989).

The first three stages of refining is carried out in the same reactor as a batch process that produce a soap stock from which fatty acids are recovered by means of acids splitting. Acids splitting process is carried out by addition of sulphuric acid to the soap stock, which causes the FFA to be separated from the medium. The resulting effluent is highly acidic and contains considerable quantities of fats and oils and very high levels of total suspended solids (TSS), chemical oxygen demand (COD), sodium and sulphate (Steffen et al., 1989; Eroglu et al., 1990; Ozturk et al., 1990; Abou-Elela and Zher, 1998). During neutralization stages, citric or phosphoric acids may be added in the wash water to reduce the residual soap in the refined oil, and to provide a better split between the oil and the aqueous phase. If phosphoric acid is used, the effluent produced will contain high concentrations of phosphorus in aqueous form (Hui, 1996).

Edible oil effluents can be treated by either chemical or biological means, or by combination of both methods (Seng, 1980). The problems with chemical treatment are the increased chemical handling costs and the production of chemical sludge, which often results in sludge with poor settling and dewatering characteristics. It is also difficult to treat and dispose the sludge produced from chemical precipitation. Precipitation with metal salts can depress the pH. Biological treatment methods offer an easy and cost effective alternative to chemical methods in treating edible oil effluents (Seng, 1980; Novotny, 1998).

Effective treatment of refinery effluent from the edible oil industry may be achieved by a combination of treatment methods, such as screening, acid splitting of oil emulsions, skimming of fats and oils and neutralization (Steffen et al., 1989). The removal of emulsified oils and other biodegradable organics present in the refinery effluent can be accomplished by screening, dissolved air floatation (DAF) and biological treatment methods (Seng, 1980; Khan and Akhtar, 1998; WBG, 1998). More stringent environmental standards have promoted the development of new intensive biological processes for treating edible oil effluents (Bekir, 2001).

The use of phosphoric acid results in effluent that contains high concentrations of phosphorus in aqueous form (Hui, 1996). The removal of phosphate from wastewater may be achieved by chemical or biological means (Momberg, 1991; Bond et al., 1999). Sometimes a chemical method is used in conjunction with a biological method (Lilley et al., 1997).

Water is a major utility in the edible oil industry, which results in the significant effluent volumes being generated hence the challenge of its disposal cannot be ignored. The volume of effluent arising from the edible oil industry is dependent on the type of product being processed and the degree of water management being exercised. The effluent of edible oil industry may contain high concentrations of oil (FOG) as oil is of concern due to their adverse effects on the environment, such as toxicity to the living organisms (Adam and Marjanovic, 1996; Bekir, 2001). In addition wastewaters from the oil industry may be high in organic content (BOD and COD), dissolved solids, sodium, sulphates and phosphates (Steffen et al., 1989; WBG, 1998) Vegetable oils are the principal sources of linoleic and linolenic acids (ISEO, 1999). (Manganyi, 2003)

In the analysis of the metropolitan data the edible oil industry, although contributing to effluent production, did not fall in the top 80% of effluent producers. Nevertheless the data received in terms of the effluent composition indicated that untreated effluent might have a negative impact on the environment. The COD values were in two cases about 1000 mg per litre with a pH ranging between 6.5 and a very alkaline 9.5. Untreated edible oil effluent would therefore contribute to oxygen depletion in the environment and a high pH may be toxic to aquatic life.

6.4.7 Fishery

6.4.7.1 Production

The catch is sorted, graded, skinned, filleted, portioned, packaged and deep – frozen. When these ships dock, the deep frozen products are off-loaded onto a conveyor belt, which transports the product directly into an airlock, where sorting takes place. Forklifts collect and deliver the product to the distribution cold storage warehouse. The catches of the “fresh fish” trawlers are stored on ice in special plastic bins in the fish holds and on docking, are off-loaded into pre-production holding chillers. At this stage the fish is sorted by species, placed into plastic bins and stored in a chiller room.

The skinning, filleting and portioning of the “fresh fish” catch is carried out in the primary processing factory, (Fresh Fish Operations – FFO). These operations are achieved by utilising various electrically operated machines, belt conveyors and operators. The waste offal is loaded directly into road transport vehicles (trucks) and transported to the fishmeal plant at Hannasbay Fishing that is located at St. Helena Bay. The fillets and portions are weighed, placed into metal forms and deep-frozen in plate freezers operating at temperatures of between –30º to –35º. The formed frozen fish is wrapped in plastic and packaged into cardboard boxes prior to removal to the cold store.

The fish smoking at Fresh Fish Operations is basically a curing process, which involves the forced circulation of smouldering oak sawdust over the hanging fish portions. The process takes place within enclosed steel chambers. On the Added Value factory, a portion of the catch is processed to crumbed and battered products such as “fish fingers”. The production of fish fingers and battered products involves deep-frying and three electrically heated deep frying units using vegetable oils. Following frying, the products are conveyed by belt to blast and plate freezing equipment prior to packaging and storage.

6.4.7.2 Effluent risk assessment

Most fish industries have two effluents discharges, namely:

Effluent from the Added Value plant, containing plant oils and organic particulate matter, such as breadcrumbs and fish offal. The effluent used to be discharged to sea, but since 1999 the Department of Water Affairs and Forestry (DWAF), requires that fisheries re-route this effluent to e.g. the Saldanha Bay municipal sewage treatment works. The Treated water is disposed of into the municipal sewer system and a third party disposes of the sludge.

The liquid effluent from the fishery industry is disposed of into the municipal sewerage system and hence poses a minimal risk to the environment.

6.4.8 Poultry

6.4.8.1 Production

Poultry processing has to deal with live chickens carrying large numbers of different micro-organisms on the skin, feathers and in the alimentary tract. A high proportion of organisms will be removed during processing. Although, contamination can occur during any stage of processing, significant reduction of the microbial load on the surface will result from scalding, plucking, evisceration, washing and chilling. After the latter processes the freshly slaughtered chicken will further be contaminated by organisms from aerosols, process-water, ice, equipment and the hands of operators (Mead, 1989).

Table 6-36 reports on the water usage, effluent production and process numbers in the poultry industry.

Table 6-36: Production figures on poultry industry

Broiler production	800 000 t/a
No of chickens processed	615 10^6/a
Water usage per chicken processed	4,5 ℓ
Total water consumption	2 767 500 000 ℓ/a

6.4.8.2 Effluent risk assessment

Poultry processing plants contribute large biological oxygen demand (BOD) loads, as well as total suspended solids (TSS) and phosphorus to wastewater. Most of the wastewater loading in the poultry industry comes from the slaughtering process when the birds are bled, scalded with hot water, rinsed up to three times, gutted, and chilled with water. Another source of water waste comes from leaving water running during breaks and shutdown times.

During this survey, no data was obtained regarding the chemical composition of poultry effluent produced in South Africa. It is recommended that more data be obtained. It is also known that at least one poultry processing plant treat their effluent before discharge, using an activated sludge system.

6.4.9 Sugar mills and refineries

6.4.9.1 Production

The incoming cane is chopped and shredded by revolving shredders. The shredded cane is then crushed between rollers and counter-currently contacted with water to ensure maximum possible juice extraction. Most of the factories are now using the technique of percolating the water through a bed of moving shredded cane (Nunn, 1993). This water is called imbibition water. The bagasse is usually used as boiler fuel but can also be used as raw material in the manufacture of other materials i.e. furfural (WRC, 1993c).

Lime is subsequently added to the juice to give a pH of about 8,5 and the solution is then heated to boiling point. These results in the precipitation of calcium phosphates denatured organic complexes and insoluble matter like soil and fibre, which are settled out in a clarifier. All associated juice is recovered from these solids by vacuum filtration.

During refining the quality of the sugar is improved and all impurities are removed. This is done by re-dissolving the raw crystals in water. After screening, the melt liquor undergoes clarification through the addition of lime and phosphoric acid and subsequent flotation of impurities. The resulting sugar concentrate is crystallised in vacuum pans and sugar crystals are recovered by centrifugation and dried (Lewis, 1993; Nunn, 1993; WRC, 1993c).

6.4.9.2 Effluent risk assessment

Wastewater flowing to the treatment units via factory drains usually consists of lost condensate, backwash and rinse water, and general washing water. Although it contains a certain amount of COD (600-800 mg/ℓ) it is also very much contaminated with fibres and soil. On average each factory produces less than 500 tons of COD.

Cooling water is re-circulated which inevitably leads to an accumulation of micro-organisms and organic pollutants, and blow down of cooling water is required. This water is largely contaminated with entrained sugar from vacuum pans and evaporators and can have COD levels of 500 to 1000 mg/ℓ. As such it is the most useable wastewater fraction in the plant if the aim is treatment with the micro-screen process. The volumes of cooling water blow down from the whole sugar industry relate to a maximum total of 4000 to 5000 tons of utilisable COD per year (for the micro-screen process).

Approximately 10% of the sugar cane can be processed to commercial sugar, using approximately 20 cubic meters of water per metric ton (m^3/t) of cane processed. Sugar manufacturing effluents typically have biochemical oxygen demand (BOD) of 1 700-6 600 (mg/l) in untreated effluent from cane processing and 4 000-7 000 mg/ℓ from beet processing; chemical oxygen demand (COD) of 2 300-8 000 mg/ℓ from cane processing and up to 10 000 mg/ℓ from beet processing; total suspended solids of up to 5 000 mg/ℓ; and high ammonium content. The wastewater may contain pathogens from contaminated materials or production processes. A sugar mill often generates odour and dust, which need to be controlled. Most of the solid wastes can be processed into other products and by-products. In some cases, pesticides may be present in the sugar cane rinse liquids. Pre-treatment of effluents consists of screening and aeration, normally followed by biological treatment. If space is available, land treatment or pond systems are potential treatment methods. Other possible biological treatment systems include activated sludge and anaerobic systems, which can achieve a reduction in the BOD level of over 95%.

6.4.10 Winery

6.4.10.1 Production

Wine is an alcoholic drink that can be made from fermented grape or other fruit juice. The process of winemaking is known to have been practised for over 5 000 years. Juice is extracted from grapes either by pressing them or by piling the grapes in a container with a false bottom and draining off the juice (free-run juice). For white wines, the juice and skins are then separated, and the juice may be settled or centrifuged to remove cloud. However, for red wines; the skins, seeds, and juice are fermented together.

The grape juice (must) is then fermented. The yeasts used in fermentation may be those naturally present on the skins of the grapes, or a pure yeast culture that is added to the must. Temperature control during fermentation is essential for the production of wine with good colour and flavour. Fermentation usually ends after 10 to 30 days, when the sugar concentration in the must has fallen low. The wine is then 'racked' or drawn off to separate the lees (sedimentary material, including the majority of yeast cells) from the wine. It may be clarified at this stage (e.g. with isinglass, a form of gelatine obtained from fish) to remove all the remaining suspended material.

Wine is usually aged in oak or redwood casks. In the case of red wines; the ageing may be two to three years. White wines however need less time, and some are not casked at all. Before bottling, wines are often blended, and preservatives may be used to limit further microbial action. Better red wines improve from ageing in the bottle and some may mature for up to 20 years. In its wider sense, wine is fermented liquor made from the juice of other fruits or from grain, flowers, or the sap of various trees.

6.4.10.2 Effluent risk assessment (reprinted with permission of Winetech)

Increases in wine production in South Africa over the past decade have exacerbated the pressure, which the industry exerts on natural resources such as water, soil and vegetation. This increase has occurred at a time when national legislation and foreign markets are becoming increasingly stringent in their demands that all factors which have the potential to affect the environment should be controlled. Such control can only be achieved through the implementation of effective environmental management systems (Van Schoor, 2000a; Van Schoor & Visser, 2000; Winetech, 2003, Vol. 2).

The by-products of cellar practices that most commonly have negative impacts on the environment are:

- Wastewater generated during cleaning
- Process water
- Solid wastes such as skins, pips, stems and lees
- Used filter materials and filter aids
- Sedimentation substances

(Van Schoor, 2000b; Van Schoor, 2001a; Chapman, Baker & Wills, 2001). Wastewater can cause salination and eutrophication of water resources (natural streams, rivers, dams, ground water and wetlands). Furthermore, wastewaters can cause soil sodicity, salinity, contamination with a wide range of chemicals, waterlogging and anaerobiosis, loss of soil structure and increased susceptibility to erosion. These impacts may be exacerbated by process interruptions. Process interruptions may stem from power failure, fire, flood, storms, overloading/underloading of wastewater treatment systems, temporary unavailability of wastewater holding dam capacity and the absence of trained operators. Where solid wastes are present, offensive odours may be generated and seepage may result in the contamination of soil and water resources, inhibiting vegetative performance (Chapman, Baker & Hills, 2001).

More than 95% of South African wineries currently irrigate their wastewater onto land through sprinkler systems (Van Schoor, 2004). It is important to use the current wastewater end use (i.e. irrigation) as the starting point when developing the winery wastewater plan, and to determine whether the current irrigation practice is beneficial or detrimental to the particular soil and crop. Under ideal conditions irrigation with winery wastewater should be no more complicated than irrigating a crop with water which contains added fertilizer (fertigation). Seasonal fluctuations and variability in winery wastewater composition may nevertheless cause imbalances. Such imbalances usually stem from mismatches between combinations of wastewater composition and irrigation method / delivery rate and the ability of the land to absorb and fully neutralize the wastewater. Run-off, or seepage resulting in pollution of soils, ground water or water courses may then occur. Since rehabilitation of contaminated soil is both costly and time consuming (Thomas, 1992), such imbalances must be avoided.

Legal requirements for winery wastewater irrigation and storage

In terms of the General Authorisations published in Government Notice Nr. 399 (26 March 2004) in terms of section 39 of the National Water Act (1998), untreated wastewater from wine cellars would rarely if ever qualify for discharge into natural water resources. Therefore, wastewater must either be treated prior to discharge into a water resource, or disposed of by some alternative method. Alternative methods of disposal are subject to the requirements of the National Water Act, 1998 and must be authorised by the DWAF (National Water Act, 1998; Van Schoor, 2001b; Winetech 2003, Vol. 6).

Characteristics of wastewater generated in South African wineries

Although various parameters may be used to evaluate winery wastewater, pH, SAR, COD and EC are of particular importance. Analyses conducted on winery wastewater indicate that the majority of South African wineries are not able to irrigate crops beneficially with wastewater unless the water is first subjected to an effective form of pre-treatment.

6.4.11 Yeast

6.4.11.1 Production

The process starts with a small sample of pure culture baker's yeast (Saccharomyces cerevisiae), which is used to inoculate the first series of fermentations of successively increasing size. The first fermentation stages are mildly aerated batch fermentations, while the last two to three stages are performed using full aeration and incremental feeding of molasses. These batch-fed fermentations are carried out in fermenters of 100 m^3 (or more) net volume (www.anchor.co.za/Anchor/technology.htm).

Fermentation time is typically in the range of 12 to 20 hours in which some 20 000 to 30 000 kg of fresh yeast is produced. When the yeast is ready to be harvested, it is concentrated and washed by centrifuge. The concentrated yeast suspension coming from the centrifuge is called liquid yeast.

6.4.11.2 Effluent Risk Assessment

Table 6-37: Yeast industry effluent data (Cape Town)

Industry type	COD (mg/ℓ)	pH	EC (mS/m)	Cl (mg/ℓ)	Sulphate (mg/ℓ)
Yeast	21 995	7	1 587	2 462	688

EC = Electrical conductivity

The effluent from yeast plants indicate COD values in the order of 22 000 mg per litre. This would have a major negative impact on the natural water environment, leading to oxygen depletion.

6.5 MINING

6.5.1 Diamonds

6.5.1.1 Production

In mining kimberlite, shafts are sunk some distance from the blue-ground pipe. Tunnels are then driven from the mineshaft to the pipe. Elevators take the kimberlite aboveground, where it is processed. The shaft of the Kimberley mine in South Africa is more than 3,500 feet (1,000 m) deep. Pipe mines are found in South Africa and Tanzania. Arkansas diamonds are also taken via pipe.

In other parts of Africa and in the rest of the world, diamonds are found in alluvial soils, or soils of sediment that have been deposited by running water. In 1962, however, diamonds were for the first time taken from the ocean floor, near Namibia.

In this process a rubber hose 12 inches (30 centimetres) in diameter is extended from a barge to the bottom of the sea. Like a huge vacuum cleaner, it sucks up gravel. On the average a ton of gravel contains one diamond, whereas it requires some 20 tons of kimberlite to yield a diamond. Production from kimberlite contributed about 9.85 million carats (or 90.3 per cent) in 2002, notable down on the output of 10.03 million carats in 2001 as a result of lower production at Diamonds 1's Finsch, Premier and Kimberley mines.

The alluvial diamond sector's contribution to total output, at just less than 1 million carats in 2002 was marginally lower than that recorded in 2001. Marine diamond production dominated by the Trans Hex Group and Alexkor was up to around 74 carats from 51000 carats in 2001.

Mines owned by Diamond 1 accounted for 95 percent or 10 402 281 carats of South Africa's recorded production compared with 10 704 967 carats in 2001. Diamond 1's production is dominated by production from its kimberlite mines (9 628 513 carats), while its Namaqualand alluvial mines contributed 773 768 carats in 2002.

Trans Hex reported total production of some 200 000 carats from alluvial and marine operations during 2002.

All water use on Diamond 1's mines, specifically during the treatment process, is monitored. Water used in the treatment plants includes both fresh and saline water.

In 2003, 59 million cubic metres of water (potable, non-potable and recycled water) were used across the Group during the year. Mines on the west coast of southern Africa used an additional 61 million cubic metres of seawater in 2003 (this excludes seawater used on prospecting and mining ships). For each carat mined by the Diamond 1 Group, 1.4 cubic metres of water (excluding seawater) were used.

In keeping with ongoing efforts to conserve water, water targets were set, implement water recovery and recycling programmes, and evaluated alternative water sources.

Excluding seawater 65.8 million cubic metres of water was used during 2004, made up of 8% potable water, 60% non-potable water and 32% recycled water. Mines on the west coast of southern Africa used 27.8 million cubic metres of seawater for operations.

6.5.2 Gold

6.5.2.1 Production

40% of the world's gold reserves are to be found in the Witwatersrand area. But the gold-bearing stone has to be mined with considerable technical expenditure from great depths (down to about 4 000 metres). To produce one fine ounce of gold, on average about 3 tons of ore, 5 000 litres of water and 600 kWh of electricity is required. For every ton of rock mined, nearly 15 tons of ventilation air is pumped underground.

Below is a description of the general steps in open-pit gold mining. The specifics of the process may vary from mine to mine.

Geologists use the latest technology such as satellite surveys and geochemistry to locate an ore deposit.

Computers are used to design the mine, which requires precise and accurate measurement of the ore deposit. Construction begins following the lengthy process of receiving permits. As holes are drilled for blasting, samples of ore are examined to determine grade and metallurgical characteristics. The broken rock is marked by type for efficient processing. Based on its metallurgical makeup, a dispatcher directs truck operators to deliver the ore to the correct processing location.

Low Grade Ore is roughly broken into small chunks and placed on carefully lined pads where a dilute cyanide solution is distributed over the surface of the heap. The solution percolates through the heap and the cyanide dissolves the gold. This solution containing dissolved gold is then collected.

High Grade Ore is delivered to a grinding mill where the ore is pulverised to a powder. Depending on its metallurgical characteristics the ore may be treated in one of three recovery circuits.

Refractory ore containing carbon is roasted to over 1,000 degrees Fahrenheit, burning off the sulphide and carbon. The product of this process is an oxide ore, which is routed to the leaching circuit. Oxide ore is sent directly to the leaching circuit where cyanide dissolves the gold. Sulphide refractory ore without carbon is oxidised in an autoclave to liberate the gold from sulphide minerals, then it is sent to the leaching circuit. Treated, high-grade ore is leached with cyanide.

The gold is adsorbed (collected) out of solution onto activated carbon. The remaining cyanide solution is recycled. The gold loaded carbon is moved into a vessel where the gold is chemically stripped from the carbon, which is then recycled. Gold is precipitated from the solution electrolytically or by chemical substitution. The pure gold is then melted into dore' bars containing up to 90 percent gold. Dore' bars are then sent to an external refinery to be refined to bars of 999.9 parts per thousand pure gold.

The Chamber of Mines Research Organisation (Comro) has estimated that for one ounce (approximately 0.0284 kg) of fine gold about 5 000 litres of water is utilised.

6.5.2.2 Effluent risk assessment

The extent of AMD impact on the environment may vary from the restricted pollution of small streams to quite profound perturbation of geo-hydrological systems on a regional basis. The Witwatersrand gold fields, exploited along a strike of 480 km, and to depths of over 4 km, provides a case study of the latter, where pumping rates of up to 130 Mℓ/day in some mines is required to prevent flooding (Funke, 1990).

This water is typically acidic with total dissolved inorganic solids (TDIS) around 3 500 mg/ℓ, mainly as sulphate, chloride and iron slats (Pulles et al., 1995), and it has been estimated that over 400 000 tons of salts from this source reaches the Vaal River annually. Apart from adding substantial costs to water provision and consumers (Heyneke, 1987), the salt load from mining activities has contributed significantly to the salination of downstream irrigation land (Herold and Bailey, 1996).

The gold mining process usually generates effluent with high levels of cyanide. Mining companies must treat this effluent before discharging it into local waterways. The problem is that finding and putting into practice the most cost-effective treatment strategy requires knowledge of a variety of disciplines including cyanide recovery and destruction processes, tailings pond design and regulatory requirements. At present, this information is scattered in sources ranging from textbooks to government files. To put it together involves meshing many disciplines such as cyanide speciation chemistry, reaction kinetics, mathematical modelling, process control, separation processes and costing. The release of deleterious substances in effluents from metal mines is related to, among other factors, the natural characteristics of the ore and uncontrollable water flows into the mine, waste rock dumps or tailings pond.

Consequently, there is no direct relationship between the production rate of a mine and the amount of deleterious substances that may be released. Tailings or waste rock at inactive sites may also continue to release substantial amounts of deleterious substances.

Table 6-38: Authorized levels of deleterious substances prescribed in the MMLER

Substance	Maximum Authorized Monthly Arithmetic Mean Concentration	Maximum Authorized Concentration in a Composite Sample	Maximum Authorized Concentration in a Grab Sample
Arsenic	0.5 mg/ℓ	0.75 mg/ℓ	1.0 mg/ℓ
Copper	0.3 mg/ℓ	0.45 mg/ℓ	0.6 mg/ℓ
Lead	0.2 mg/ℓ	0.3 mg/ℓ	0.4 mg/ℓ
Nickel	0.5 mg/ℓ	0.75 mg/ℓ	1.0 mg/ℓ
Zinc	0.5 mg/ℓ	0.75 mg/ℓ	1.0 mg/ℓ
TSM	25.0 mg/ℓ	37.5 mg/ℓ	50.0 mg/ℓ
Radium-226	10.0 pCi/ℓ	20.0 pCi/ℓ	30.0 pCi/ℓ

Note: All concentrations are total values with the exception of radium-226, which is a dissolved value after filtration through a 3-micron filter.

Typically the major sources of contamination in deep gold mines originate from either underground or surface sources, or from a combination of both. The typical underground sources of contamination are:

- pyrite oxidation of stopes
- inadequate underground settling
- fissure water
- waste explosives
- faecal contamination

The typical surface water sources of contamination are:

- surface rock dumps
- surface sand dumps
- slimes dams
- neutralization chemicals
- spillage from plant areas, pipelines and slimes dams
- sewage
- contamination run-off from hostels

- livestock grazing

Table 6-39: Summary of contaminants, their sources on the mine and areas impacted

Contaminant	Typical source	Areas affected
Metals Iron Manganese Zinc Lead Copper	Pyrite oxidation in underground stopes & surface rock dams with dissolution of metals	Sediment, groundwater, surface waters, macrophytes, biota
Sulphate	Pyrite oxidation in underground stopes & surface rock and sand dumps & slimes dams with production of sulphates	sediment, groundwater, surface water

The impacts result primarily from the following water quality problems:

- nutrients – mainly nitrate, ammonia and phosphate
- high pH
- metals – manganese, lead, copper, zinc, cadmium and nickel
- salts – calcium, sulphates
- microbiological – faecal coliforms
- toxins – cyanide

6.5.3 Iron ore

Annual production figures as obtained from Iron ore 1 are given in **Table 6-40** below.

Table 6-40: Iron ore 1 Production figures

2003	Production ('000 t)
Iron ore	133 746
Sishen	97 927
Thabazimbi	35 819

6.5.4 Limestone and dolomite

6.5.4.1 Production

It is estimated that world production of limestone is of the order of 5 billion tons per year. This figure includes limestone used as dimension stone and as aggregate, as well as that used in the cement, chemical and agricultural industries.

World lime production is estimated at greater than 200 million tons per annum, and lime ranks as the fifth most commonly used chemical, after sulphuric acid, nitrogen, oxygen and ethylene. The terms, lime and lime products, refer to quicklime (CaO) and slaked lime ($Ca(OH)_2$). The term, lime, is frequently used incorrectly to describe limestone products, such as agricultural limestone.

Cementitious products are derived from a blend of limestone, aggregate, shale, sand and silica; these products are used as masonry cements, ready mix cements, mortars and plasters in the construction industry. In South Africa the principal use of limestone is in the manufacturing of cement, followed by metallurgical applications (as a fluxing agent in steel making), the manufacturing of lime and agricultural uses. Limestone and dolomite are not as widely used in South Africa for aggregate or dimension stone as elsewhere in the world.

Lime, limestone and dolomite products are used in the following applications:

- Agriculture – fertilisers, fungicides, animal feed
- Construction – mortar, cement, whitewash, building stone

- Manufacturing – glass, food processing, steel refining, papermaking, leather applications
- Metallurgy – steel refining, fluxing, neutralising agents, flocculation, causticisation
- Other industries – medicines, bleaches, water purification, effluent treatment, explosives, Ca-supplement in food, oil spill cleanup, adhesives, insulation and pH control.

6.5.5 Platinum

6.5.5.1 Production

Platinum occurs in the Bushveld Complex largely falling within the North-West Province (Western Limb) and Limpopo and Mpumalanga Provinces (Eastern and Northern Limbs). The Bushveld Complex is the most platinum rich region in the world (Barker and Associates, 2002). Two main platinum reefs occur, namely Merensky, mined since 1923, and UG2, mined since the late 1980s. Approximately 23 mines are currently mining the reefs with several others in the planning and feasibility stages.

6.5.5.2 Effluent risk assessment

The water systems and waste streams in the mining and processing operations and the management thereof are presented in **Table 6-41**. Water requirements (often drawn from potable supplies) for the mining and concentrator operations per mine are in the region of 600 mega litres per annum (Ml/a) to 22 900 Ml/a depending on the size of the mining operation and the level of recycling. The more water-efficient mines are currently using between 600 and 800 litres of make-up water per tonne of ore milled.

Water requirements for a single smelter and refinery (base and precious metals) are in the region of 3300 Ml/a. Water management at mines, including water containing waste, is controlled by the National Water Act No. 36 of 1998 (NWA) and the Mineral and Petroleum Resources Development Act (MPRDA), Act No. 28 of 2002. Tailings dam design, operation and decommissioning must comply with the Department of Minerals and Energy, Mines Health and Safety Inspectorate Guidelines for Compliance of a Mandatory Code of Practice on Mine Residue Depositions (31 May 2001) and the South African Bureau of Standards Code of Practice for Mine Residue (SABS 0286:1998).

Table 6-41: Water and waste management at platinum mines

Water and waste	Management
Water systems	
Potable water	Use of potable water is minimised by optimising recycling of process water.
Process water (previously used potable water, excess groundwater pumped from the shafts, treated sewage effluent, return water from the tailings circuit and dirty storm water runoff)	Recycling of process water enables platinum mines to aim for a zero discharge policy to protect water resources. Process water is pumped via a network of pipelines around the mining site as required. Sumps and silt traps are used to reduce the particulate content of recycled water.
Sewage (raw and treated)	Sewage is usually treated in mine operated sewage plants. Treated final effluent is pumped to the return water dam for reuse in the process but in some instances may be discharged to the nearest watercourse.
Underground water from dewatering of the shafts and underground operations	Water from underground is pumped to surface dams for recirculation underground. Excess water is pumped to the return water dams or used for irrigation and dust suppression.
Storm water (clean and dirty)	Clean storm water is diverted around infrastructure to its natural watercourse. Dirty water is collected on site and either reused on the mine or disposed of by evaporation. Exposed surfaces within dirty areas (such as the concentrator, smelter, refineries, waste rock dumps and tailings dam) are kept to a minimum to minimise the volume of dirty runoff generated (for example, by careful design, re-vegetation, roofing) and the potential loss of ‘clean’ runoff to the watercourse/catchment.

	Catchpits and energy dissipation are used to attenuate storm flows to reduce the risk of erosion of watercourses, particularly where clean water diversions end and where watercourse crossings are needed.
Waste streams	
Waste rock and tailings	The pollution potential of waste rock and tailings is assessed using the principles of Minimum Requirements, as described in the guidelines published by DWAF (DWAF, 1998). Waste rock and tailings typically have low sulphur concentrations and sufficient buffering capacity to neutralise any acidity that is produced, unlike gold tailings, which produces acid mine drainage. Although the production of acidity is unlikely, there is the potential that the sulphur in the waste may oxidise to produce sulphate. This sulphate could then leach from the dumps and dams and contribute to the salinity load of the receiving environment.
Sewage sludge	Sewage sludge is dried in sludge drying beds, which are concrete lined. Dried sludge undergoes final stabilisation, prior to transfer to the tailings dams where it provides stabilisation media for re-vegetation.
Slag produced at the smelter	Furnace slag from the smelter is disposed of via the tailings dams.
Effluent from the refineries	Effluent is stored in dams, which are lined and have leachate detection systems. The effluent is disposed of via evaporation. The residue is stored in lined encapsulation dams.
Oil, greases and spills	Spills and wash down water flows via an oil trap to the process water system. Waste from the oil traps, used oil and empty oil and grease containers are removed by a reputable waste removals company for recycling, where possible, or disposal.
Domestic waste	Domestic waste is removed by a reputable waste removals company and land filled.

Potential impacts on surface and groundwater quality and quantity may be caused by:
- spills and leaks;
- unnecessary wastage of raw water;
- losses from the system by not maximising re-cycling of ‘dirty’ water;
- diffuse and point source releases of ‘dirty’ water to the environment.

Parameters of concern are:
- elevated salinity, particularly the anions sulphate and chloride and cations calcium, magnesium and sodium;
- elevated nutrients (e.g. nitrate, ammonia and phosphate) due to explosives residues (nitrate and ammonia only), fertilizer from surrounding agricultural activities and sewage;
- elevated heavy metals (primarily evident in process water at certain mines only).

Elevated levels of salinity, nitrate and ammonia tend to occur in the process water system and may enter the environment, impacting on surface and groundwater resources, if water management systems and recycling on the mine are not optimised. Ground water quality around tailings dams typically indicates elevated salinity and nitrate due to seepage of tailings water into the underlying aquifer.

Management measures to mitigate the potential impacts and ensure compliance with Regulation 704 and Regulation 527 have been committed to by many of the platinum mines. A brief overview of these commitments is given below.

- Design and operate all mine infrastructure to minimise the risk of pollution.

- Manage water use (including abstraction, storage, use and discharge) at the mine in an efficient and effective manner to minimise disturbance to water resources and the users of those resources.
- Manage storm water and flow in watercourses by proper design and maintenance of all storm water containment facilities, diversions and linear infrastructure, such as roads, pipelines and conveyors.
- Develop water management tools, such as salt/water balances and the use of targets.
- Manage land use by conserving topsoil resources, limiting erosion and rehabilitating disturbed land.
- Maintain good housekeeping practises, for example clearing and disposal of spills in an appropriate manner and proper storage and handling of waste.
- Monitoring of surface and ground water according to an agreed monitoring programme to identify trends. This information assists with management of impacts within the mine lease area and on downstream or down gradient users. Conduct regular internal reviews and audits to ensure the mine is operating in accordance with its environmental commitments in the EMPRs, water use licence, environmental management system and/or ISO 14001.

6.5.6 Coal

6.5.6.1 Effluent Risk Analysis

Limited information on coal mine water effluent could be obtained. The only detailed analysis was reported in 2001 by Pulles et al., who reported on a generic water balance for the SA coal mining industry as follows.

"In order to be able to plan research initiatives and to have benchmarks against which mine water management on coal mines could be measured, a need was identified to develop a generic water balance for the coal mining industry. The overall water balance for the South African coal mining industry indicates that on average, 133 1 of water is used for each ton of coal that is mined. A large percentage, approximately 85%, use underground or pit water as a water source compared to some 57% that extract board water as a water source. Volumetrically, the primary source of water came from ground water and river water, contributing 35.9% and 32.3% respectively. Board water as a primary source, contributed 12.7% to the total water source. Beneficiation plants consumed the largest portion, i.e. 26.1%, of the water used by the industry, compared to mining operations that used 25% of the available water. Six percent of the total water consumed by the coal mining industry was used for road wetting. Approximately 31% of the available potable water is used for domestic purposes, with 18.8% of the latter volume of water actually being consumed. The incompleteness of water balances on South African coal mines is reflected in the large percentage, i.e. 51.1% of the effluent being discharged into unspecified sinks. These unspecified sinks could include loss of water that is difficult to quantify, such as ground water, but could also indicate a lack of good water balance information for each individual mine. In general, water is lost in the following manners: human consumption –4.5%; rivers –8.7%; evaporation –30.9%; and water lost as moisture with the coal and discard material –4.8%. In general terms, the state of water balances at coal mines is poor with insufficient detail being provided to enable a proper assessment of the status of water management at these mines. It must, therefore, be concluded (on the basis that one cannot manage what you cannot measure) that there is an equivalent problem with the status of water management on coal mines. There are a few exceptions to the above generalisations where mines, although not perfect, have made significant effort to develop detailed water balances that are being refined and improved upon on an ongoing basis. The lack of appropriate water balances is believed to be a serious hindrance to effective mine water management that needs to be addressed and remedied as a matter of priority".

Table 6-42 Coal 2: Water use and effluent figures (2004)

WATER SUPPLY	
Potable Water from an External Source (1000 m^3)	4 305
Non-Potable Water from an External Source (1000 m^3)	993
Water Recycled in Processes (1000 m^3)	9 404
EFFLUENT TO SURFACE WATER	
Effluent to Surface Water (1000 m^3)	7 177
TDS to Surface Water (tonnes)	7 059
TSS to Surface Water (tonnes)	592
Sulphates (tonnes)	3 671
EFFLUENT TO OTHER	
Effluent to Irrigate Land (1000 m^3)	138
TSS to Irrigation (tonnes)	0.68
TDS to Irrigation (tonnes)	31
Effluent Treated by Third Party (1000 m^3)	5 928
TDS to Third Party (tonnes)	11 410

6.6 ELECTRICITY GENERATION

6.6.1 Overview

At present, approximately 192 000 GWh of electricity per annum is produced in South Africa by 29 power stations situated countrywide. The amount of electricity generated is constantly increasing to meet demands. For example, the total amount of power generated increased from 150 000 GWh in 1992 to 192 000 GWh in 2002, which indicates a growth of almost 20%.

Water is one of the major resources required to generate electricity in South Africa, especially in coal-fired power generation plants. To produce 192 000 GWh of electricity, approximately 245 000 Mℓ of water per annum is consumed. There are three main role players responsible for Power Generation in South Africa. These are:

- Eskom
- Government (Municipal power stations)
- Public private partnerships (Independent power producers).

Of the 29 power stations in South Africa, Eskom has 24 power stations situated countrywide. Eskom provides approximately 95% of the electricity produced in South Africa. The Eskom power stations are made up as follows:

- 13 coal-fired stations
- 1 nuclear power station
- 2 pumped storage stations
- 6 hydroelectric stations
- 2 gas-turbine stations

Apart from Eskom power stations, there are 5 smaller coal-fired stations operated by either regional Municipalities or Public private partnerships. These include:

- Athlone power station, operated by the City of Cape Town
- Kelvin power station, operated by AES Sirocco & Global African Power
- Rooiwal and Pretoria West Power Stations, operated by the City of Tshwane
- Bloemfontein power station, operated by the Bloemfontein Municipality.

The generating capacity of these stations are given below.

Table 6-43: Electricity generating capacity of different types of power generation facilities

TYPE	NET MAX CAPACITY (MW)	% OF TOTAL
Coal Fired: Eskom Municipal & Private	 34 882 900	 87.7 1.5
Nuclear	1 930	4.9
Pumped Storage	1 400	3.5
Hydro-electric	600	1.5
Gas-turbine	342	0.9

The nuclear and most of the coal fired power stations are the only power stations that are fully operated at all times. These stations are referred to as 'base load' power stations, which operate on a 24-hour basis to ensure a constant supply of energy for normal daily consumption.

Some of the coal fired power stations together with hydroelectric and pumped storage schemes are only used during South Africa's peak periods, such as the early hours of the morning and evenings. Gas-turbine power stations are only used during extreme emergencies due to their very high operating costs.

6.6.2 Production process

In principle, a power generation process occurs in two loops or circuits, in which the working fluid for both circuits, is water.

The main components of the primary circuit include:

- Steam generator (either a boiler or reactor),
- Steam turbine,
- Condenser and
- Feedwater system (pumps and heaters)

Water must be heated to produce steam, which requires the input of latent heat. When the steam is condensed in the condenser, the latent heat is released and passed into the cooling water, in the secondary circuit.

The secondary circuit contains the:

- Condenser
- Cooling tower and
- Recirculating pump

The condenser is the main part, which joins the primary and secondary circuits.

TYPES OF POWER GENERATING PROCESSES

Power generation processes can be divided into four major types. The principle of steam generation (as described above) is the same for all types, but the fuel source and type of steam generator differ. Types of power generation processes include:

- Coal fired processes
- Nuclear processes
- Hydro-electric processes
- Gas turbine processes

Approximately 90% of power generated in South Africa is generated by means of coal-fired processes. This results from the fact that coal is one of the most abundant sources of energy in South Africa, and that coal mining in South Africa is relatively cheap compared to the rest of the world (in Europe costs are almost four times higher).

For the purpose of this document, we will only discuss the coal fired process. Please refer to Van Zyl et al. (2003) for information on the other power generation processes.

COAL FIRED PROCESS

Although electricity cannot be stored or harnessed from nature directly electrical energy can be extracted from a fuel source such as coal, oil or natural gas. Coal fired power stations are also referred to as fossil fuel or thermal power stations.

Internationally, as well as in South Africa, coal is currently the most widely used primary fuel, accounting for approximately 36% of the word's electricity production. South Africa is the fifth largest coal producing country in the world, exporting 25% of production. Of the remainder, 53% of the coal produced is used for electricity generation.

Table 6-44: Usage of SA coal

	Mt	**Reference source**	**Reference Date**
RSA Consumption (2002)	**155**	**World Energy Council**	**2002**
Power Generation	100	IEA Clean Coal Centre	2002
Synthetic Fuels	30	IEA Clean Coal Centre	2002
Coke production	3	IEA Clean Coal Centre	2002
Other	22	By difference	
RSA Export (2002)	**70**	**IEA Clean Coal Centre**	**2002**

Coal is transported from the stockyard via storage silos to boiler bunkers by means of conveyor belts. From the boiler bunkers, it is fed to mills where it is pulverised to form dust, which is then blown through boiler burners into a furnace. In the furnace, it burns at a temperature of approximately 1300 °C. A heated air stream for combustion purposes is forced by the pressure of a forced fan or sucked by an induced daft fan, to move through the boiler. The chemical energy of the fuel is converted to heat energy, which is then taken up by the boiler feed water to produce steam.

Fly ash and coarse ash are produced during the combustion process. The ratio of coarse to fly ash is a function of the mill type and is generally 1 to 9 for tube mills or 2 to 8 for ball mills. The more modern power stations use tube mills and dispose of the ash in a relatively "dry" state. Dry ashing entails the quenching of the coarse or bottom ash with low salinity effluents prior to mixing with the fly ash, which has been conditioned with effluents for dust suppression. Older power stations generally use ball mils and employ a hydro vac system to remove the ash from the respective primary receivers in order to pump it as slurry towards the ash dams. The excess water decant via penstocks to dams from where it is reused. Smaller power stations often transport ash with road or rail trucks following a dewatering process.

Following the combustion process the air stream, contains the combustion by-products (sulphur, carbon dioxide, etc.) and fly ash. Fly ash emanating from modern (beyond 1980 designs) contains less than 1% carbon. Carbon in ash from older power stations could be in the order of 4%. The fly ash is separated from the flue gases in scrubbers, which may be electrostatic precipitators, bag filters or cyclones. Cleaned flue gases pass to the atmosphere through chimneystacks.

In the boiler the chemical energy contained by the coal is transferred to the water. The water is converted to steam at a high temperature and pressure. Modern fossil fired plants employ re-heaters to enhance the efficiency of the energy conversion process.

The steam produced pass through super heaters to high-pressure steam turbines. Exhaust steam is returned to the boiler re-heaters and then channelled to the intermediate-pressure turbine and low-pressure turbines. The rotating shafts of the steam turbines are coupled to electrical generators. The electricity passes from the generator stator windings to a transformer. The speed at which the steam turbine is operated is very important, as this determines the electrical frequency, for example in South Africa we use 50 Hz.

Spent steam is condensed and pumped via feed heaters and de-aerators to the boiler feed pumps and then back to the boiler to repeat the cycle. This water cycle between the boiler and condenser is often referred to as the Demineralised water cycle. The condenser in which spent steam is condensed is essentially a heat exchanger operated at near vacuum conditions on the steam turbine exhaust side. On the other side of the condenser, water cooled in a cooling tower is pumped by a re-circulating pump into the condenser to remove the latent heat of the low-pressure steam, and allow the steam to phase change back into liquid water. The water cycle between the condenser and cooling towers are called the “Cooling water cycle”.

The cooling fluid is normally concentrated raw / river water but could also include treated sewage or mine effluent. Power stations at the coast generally employ sea water for cooling purposes. The cooling fluid is normally treated with biocides to control either microbial and or marine organisms while de-carbonation and clarification is essential to operate cooling water systems at elevated cycles. Make-up water to these concentrated cooling water systems is generally not pre-treated because of capital and operational cost considerations. De-carbonation and clarification of the concentrated cooling water with cold lime softening is much more efficient at elevated cycles of concentration. At most Municipal power generating plants, treated sewage water is used for cooling purposes.

In the condenser the demineralised water cycle and concentrated cooling water is separated from each other by a ±1.2 mm thick admiralty brass tubes. The demineralised cycle is under vacuum and in leakage of cooling water is detrimental to demineralised cycle components

Coal fired processes make use of two different types of cooling processes, namely wet evaporative cooling and direct or indirect dry cooling.

In wet cooling towers the hot cooling water, which has circulated through the condenser, is sprayed through nozzles into an upward moving air stream in a tower at a height of approximately 13 m. The up draught of air through the cooling tower is due to convection. The heat is absorbed by the air and dissipated into the atmosphere. However, water vapour in the form of mist is also lost to the atmosphere.

Approximately 80% of the water consumed at wet-cooled power plants is lost due to evaporation from the cooling towers. Not all the power plant components could be cooled with air as the dry bulb temperatures often exceeds the upper temperature limit of these components. Power stations, which are referred to as dry cooled stations thus still employs wet cooling for certain plant auxiliary and ancillary systems. These systems are relatively small and evaporative losses are in the order of 0.022 ℓ/uso.

There are two basic dry-cooling systems:

- Indirect dry-cooling.
- Direct dry-cooling

Indirect dry cooling units utilises a system whereby the water used for steam generation is passed through radiators installed in the cooling towers. The advantage of dry cooling is that water losses due to evaporative cooling of condensate are eliminated, resulting in a reduction of total amount of water consumed by the power station. Direct dry cooling systems uses air cooled condensers.

6.6.3 Water distribution

6.6.3.1 Coal-fired power generating plants

The distribution of raw water to the main four water systems as discussed earlier for coal-fired plants is shown below.

Table 6-45: Distribution of raw water for coal fired plants

	% of raw water		
Water cycle	**Wet Cooling**		**Dry Cooling**
	Eskom	**Municipal**	**Eskom**
Total water consumption	1.7 to 2.20 l/kWh		0.08 to 0.10 ℓ/kWh
Demineralised water cycle	2 to 5%	3-12%	30%
Cooling water cycle	82-91%	63-85%	21%
Potable water cycle	1%	3-10%	14%
Ashing water cycle	5-14%	5-20%	24%
Evaporation in storage dams	Negligible		4%
Dust suppression	Negligible		7%

Note: Water often cascade from one system to another. The Eskom values represent consumptive use for each area.

6.6.3.2 Nuclear power generating plants

The distribution of raw water to the three water systems for nuclear plants (refer to Van Zyl et al. for more detail) is shown below.

Table 6-46 Distribution of raw water for nuclear plants

	% of raw water used
Primary system + secondary system (Demineralised water)	24-33%
Tertiary system (Cooling)	67-76%
Third parties	0.3-0.5%

6.6.4 Water use data

The mean raw water intake per unit sent out (RWI) gives a good indication of the water efficiency of a power generating process. Raw water intake and qualities obtained during the survey are presented in the tables below.

6.6.4.1 Coal-fired power generating plants

The water intake for coal-fired power plants is summarised in the table below. Data was gathered for ten Eskom coal-fired plants and two municipal plants. The Bloemfontein Power Station as well as the Athlone Power station was found to be non-operational at the time of this study. These stations are at present only re-fired in winter times. The Pretoria West Power Station was not willing to co-operate in this research project.

Water received by most Eskom coal-fired power generating plants comes from nearby rivers, including the Vaal, Usutu and Komati water systems as well as the Slang River and Mogol River.

Table 6-47: Mean raw water intake per power generated (ℓ/kWh) for coal-fired processes.

	Raw water intake / unit sent out (l/kWh)		**Water received (Ml/month per station)**	
	Wet-cooled	**Dry-cooled**	**Wet-cooled**	**Dry-cooled**
ESKOM POWER STATIONS River water	1.70-2.20	0.08-0.10	1500-4700[1]	220-335[2]
OTHER POWER STATIONS Treated sewage water Municipal water	1.80-6.49		557.55-646.63 11.15-67.38	

Water received by municipal plants include:

- Treated sewage water from nearby sewage works which are used for cooling purposes
- Rain water
- Municipal water sources that are used for domestic purposes as well as primary energy demands.

6.6.4.2 Nuclear power generating plants

Water received by the nuclear power generating plant in the Western Cape comes from three different sources, including:

- Municipal water
- Water received from the municipality is used for domestic, horticultural and primary energy demands
- Borehole water (Borehole water is primarily used for primary energy production)
- Seawater (Seawater is only used for cooling purposes and is afterwards returned to the ocean)

[1 and 2] Maximum load during dry season

Table 6-48: Mean raw water intake per power generated (ℓ/kWh) for nuclear processes

Water Source	Average use / consumed (ℓ/kWh)	Water consumed / received Mℓ/month
Municipal water	0.073-0.090	55.97-105.54
Borehole water	0.000-0.005	0.00-1.35
Sea water (non consumptive)[3]	156.52	207 360-214 272
Total consumptive use	0.073-0.090	87.1-123.2

6.6.5 Effluent data

6.6.5.1 Coal-fired power generating plants

A summary of effluents produced at coal fired power generating plants is given below.

Table 6-49: Effluent generated at coal fired power plants

	Eskom (ℓ/kWh sent out)	**Municipal (l/kWh)**
Tower evaporation	Modern Power Station = 104 Mℓ per day Basis: 1.546 ℓkWh so @ 35.5% overall thermal efficiency 6 by 600 MW MCR[4] Net Capacity 575 MW Station load factor 81%. Therefore: Daily average $\frac{(600-25)\times 6\times 24}{1000}\times 1.546\times 0.81=104\ Ml\ \ per\ \ day$ Old Power Station = 24.6 Mℓ per day Basis: 1.942 ℓ/kWh so @ 26.2% overall thermal efficiency $\frac{891\times 24}{1000}\times 1.942\times 0.81=24.6\ Ml\ \ per\ \ day$	2.52
Dirty process water disposed with ash	Cooling tower blow downs 2.6 to 5.47 Mℓ per day Demineralised water production effluents 15 to 193 m^3 per day	
Water discharged to waste	Zero Liquid Effluent Discharge barring seepage losses	1.92
Water reclaimed to ash system	100% Recovery, treatment and re-use of waste water including approximately 480 Mℓ per month polluted mine water	0

6.6.5.2 Nuclear power generating plants

A summary of effluents produced at nuclear power generating plants is given in **Table 6-50**.

Table 6-50: Effluent generated at nuclear power plants

Effluent type	Amount (Mℓ/month)
Nuclear island[5] sewage plant effluent (Sludge disposed at Vaalputs)	1.2
Treated radiological waste[6]	1.6
Conventional liquid effluent (Demineralised water production effluents plus sea water leaks)	89.443

[3] Once through cooling system at a flow of 40 m^3 per second per unit.
[4] Maximum capacity rating
[5] Potentially radio active area
[6] Volume of effluent from the nuclear island prior to evaporation and encapsulation in concrete for disposal at Vaalputs

The following tables provide information on the quality of the effluent resulting from the various processes in coal fired power generation.

6.6.6 Effluent risk assessment

Twenty-nine power stations situated countrywide collectively produces approximately 192 000 GW of electricity per annum. To achieve this, approximately 245 000 Mℓ of water is consumed. Although effluent produced is minimal, up to 80% of this water is lost through evaporation in cooling towers.

Four major types of power generating processes utilized in South Africa have been identified, namely Coal-fired, Nuclear, Hydro-Electric and Gas Turbine Power Generating Processes. Of these, Coal Fired Processes has the highest water consumption.

The average raw water consumption/unit sent out (ℓ/uso) is dependent upon the type and overall thermal efficiency of power generating process, whether open or closed loop cycles are used, the type of cooling and ashing processes utilized, as well as the quality of raw water. The average consumption was found to be 1.95 ℓ/kWh for recycling wet-cooled coal-fired plants, 6.5 ℓ/kWh[7] for once- through wet-cooled coal-fired plants, 0.09 ℓ/kWh for dry-cooled coal fired plants and 0.198 ℓ/kWh for nuclear plants. Hydroelectric processes do not consume any water, but merely uses the energy in it, and no water is required for power production in gas turbine plants.

Improvements in raw water consumption can be achieved through the use of dry-cooled systems and water recycling in the case of municipal plants. It is suggested that target ℓ/uso are set at a maximum of 2.5 ℓ/kWh for wet-cooled coal-fired processes and 0.14 ℓ/kWh for dry-cooled power generating processes.

The power generating industry continually assesses the management of water resources and complies with water legislation as determined by the Department of Water Affairs and Forestry. The National Water Act requires all power stations to be registered as water users. In recent years, measures have been taken to reduce the water intake and pollution potential of power generating stations. These measures included the implementation of zero effluent discharge systems, the installation of dry-cooling and dry ashing systems, and the installation of desalination plants to treat mine water which can be used as raw water source as well as improved management and operation of processes.

[7] The bulk of this water is discharged thus not consumed

Table 6-51: Quality of cooling water: Wet-cooled coal fired processes

	CaH mg/kg as $CaCO_3$	Cl mg/kg Cl	Fe mg/kg Fe	K mg/kg K	K25 µS/cm	M Alk mg/kg as CaCO3	MgH mg/kg as CaCO3	Na mg/kg Na
Eskom	200-500	< 400	0.89-1.1	< 500	2000-4000	80-120	70-150	< 500
Municipal	Not available	64.0-256.0	Not available	Not available	69.0-256.0	Not available	Not available	Not available

	P Alk mg/kg as $CaCO_3$	pH	SiO2 mg/kg SiO_2	SiO_2xMgH	SO4 mg/kg SO_4	TH mg/kg as $CaCO_3$	Turbidity NTU	Zn mg/kg Zn
Eskom	< 5	8.3 to 8.7	< 167	< 25 000	750 or < 1500	280-650	< 100	0.1-0.25
Municipal	Not available	8.26-8.75	Not available	Not available	Not available	Not available	Not available	Not available

Table 6-52: Quality of ash water

	CaH mg/kgas $CaCO_3$	Cl mg/kg Cl	K mg/kg K	K25 µS/cm	M-Alk mg/kg as $CaCO_3$	MgH mg/kg as $CaCO_3$	Na mg/kg Na
Eskom	1322 to 1760	35 to 129	38-97	5680 to 6140	721 to 1237	< 2 to 7	160 to 320

	P Alk mg/kg as $CaCO_3$	pH	SiO_2 mg/kg SiO_2	SO4 mg/kg SO_4	TH mg/kg as $CaCO_3$	Turbidity NTU
Eskom	689 to 1218	11-12	2.3-7.3	380.0-1820	1760 to 2040	0.42-17.4

Note: Typical ash water quality for wet ashing power stations operating on worst and best case raw water

7 GENERAL DISCUSSION

7.1 EXISTING DATABASES

In general, the existing databases were found to be unsuitable for this project, inaccurate or out of date. Still, some literature that was reviewed as part of the investigation of existing databases, were of great value. This includes concepts (like the SIC coding system used by Statistics SA) used for other studies and Government publications on current and projected water resources (NWRS).

7.2 METROPOLITAN COUNCILS

Most of the major metropolitan areas could provide some data. The data from the metropolitan areas ranged from being reasonably accurate to very incomplete and/or inaccurate. In the case of the Johannesburg Metropolitan Council no data was supplied in terms of effluent production. The Tshwane Metropolitan Council supplied accurate data for water use and effluent and their records were in real-time and generally up-to-date. The data supplied by metropolitan councils that have records on effluent production and water use, was used to identify those sectors that utilise 80% of the water or contribute to 80% of the effluent produced in each area. This analysis was useful in terms of identifying and focussing on individual sectors in these metropolitan areas.

At present there is no standard procedure in place for metropolitan councils on what to monitor with regards to effluent quality. As a result not all metropolitan councils can give accurate account of the effluent produced for a specific industry (with regard to volume and quality) relative to its water use.

7.3 SECTORAL INFORMATION

One of the most challenging parts of this study was to obtain data on water use and effluent production from the different sectors and, in particular, from specific companies. In some cases, companies were unwilling to co-operate in terms of providing data. This was mainly because of issues concerning confidentiality. In some cases the data reflected daily values that fluctuated, depending on the time the flow measurements were made. It was not surprising that the data from individual companies could not be balanced with the data received from metropolitan councils. The analysis of sectoral data could at best be used to determine trends, rather than perform accurate data analyses, making it impossible to calculate the total pollution load from a particular sector. Obtaining data from companies outside of metropolitan councils proved to be even more difficult.

Although information was obtained from numerous companies in the industrial, food and beverage, mining and electricity generation sectors, the majority of the companies contacted did not perform analyses for the full spectrum of hazardous substances in the effluent. As a result, these companies could not give account of the exact composition of the wastewater resulting from the industrial activity.

7.4 DATABASE

All the data gathered for this first order inventory was entered into a MS Access database that enables the user of the database to locate, sort, combine and extract useful information on the whole range of variables related to water use and effluent production for each industry covered in this study. The software program used has the flexibility to combine and export information spreadsheets so that a multitude of statistical parameters can be calculated and tables and graphs produced for interpretation of the data.

During the construction of the database it became apparent that the data obtained from the various sources was not only different (with regard to format, units etc.), but that in fact many of the data sets did not contain all the important information relevant to that specific industry. This incompleteness of data was mainly due to inadequate monitoring and/or hesitancy of companies to disclose sensitive information. As a result the existing database contains some data sets that are incomplete and in some cases, out of date.

7.5 THREAT ESTIMATION

During reviews of the chemical risk analyses given in literature for the various industries, it became evident that most industries produce effluents that are hazardous to the environment. When considering this, and studying the data provided on the chemical analyses of effluent from South African companies, it became apparent that the chemical analyses performed by South African industries were either incomplete or these companies did not provide all their available data.

In estimating the threat that effluent may pose, three major factors were considered:

- The destination of the effluent
- The chemical composition of the effluent
- The quantity of the effluent

In the majority of cases where the effluent is discharged into a municipal sewerage system, the risk was limited (note that many of the industries where data was provided, did not indicate the destination of the effluent).

In terms of the chemical composition and quantity of the effluent, there was not a single industry that would not have some negative impact on the environment if the effluent were to be discharged into a natural water system, and more so for greater quantities of effluent.

7.6 SYNTHESIS OF WATER USE AND WASTE PRODUCTION

The analysis of data obtained from metropolitan councils indicated that, as far as the industrial and food and beverage sectors were concerned, three sub sectors could be identified as major water users. These were breweries, paper and pulp industries and textile industries. Subsequently, these industries were also major contributors to the total effluent production in metropolitan areas. The food and beverage industry as a whole was identified as a significant producer of effluent in the sense that this industry was by far the most common industry present in all the metropolitan areas and it contributed significantly to the production of effluent.

Individual effluent risk assessments indicated that one of the major concerns associated with the effluent resulting from the food and beverage industry was the high COD and BOD values. Once released into a water system, high COD and BOD can lead to oxygen depletion of the water resource, which, if not a controlled environment (e.g. a sewerage system) can have a negative impact on aquatic life. High oxygen demands were also associated with the textile and paper and pulp industries.

As far as the mining sector in South Africa was concerned, the survey indicated that the four major water users were platinum, gold, diamond and coal mining. Although the information received from the mining sector on effluent production was minimal, it would be safe to assume that these mining sub sectors were also responsible for a significant volume of effluent produced. The effluent resulting from mining activities was very often not sent to municipal (or other third party) sewerage works, so that should this untreated effluent be disposed of in natural water systems, it can have major negative impact on water quality. Mines generally do have systems in place to minimise spillages to the river system (e.g. cut off trenches, return water dams etc.), but these are not always adequate and pollution does occur.

Although the electricity generation sector was considered a major water user in South Africa (accounting for 2% of the total water demand in the country according to the NWRS), the effluent resulting from this sector was minimal (2% of water supply), as most of the water evaporates in the coal fired process. Pollution from some ash dumps needs to be contained and carefully managed.

The biggest limitation experienced in the execution of the project was the reliance on the co-operation of numerous institutions (national government, local authorities, individual private sector companies). Some organisations showed interest in the project, and were transparent about the information they had Unfortunately, many institutions were reluctant to provide the necessary information, mainly because of concerns regarding confidentiality of data, fear of prosecution and concerns that transparency regarding effluent production could lead to them being forced to incur additional treatment costs. Many of the surveyed industries did not conduct any chemical analyses on the effluents that they produce and where chemical analyses were done, they very seldom went beyond a few basic parameters like COD, phosphate and nitrate. The current data therefore merely indicates a trend rather than determining the exact pollution load to the environment.

In the determination of risk that the effluent may pose, a very important factor that was considered was whether the effluent was discharged into a municipal sewer system or whether the effluent was discharged directly into a natural watercourse without treatment. In terms of the brewery industry, most of the breweries were located within a metropolitan council and hence the effluent discharged into a sewer so that it poses minimal risk to the environment. Similarly for the dairy industry and the pulp and paper industry, where many of the facilities were located within a metropolitan council. However, in some cases pulp and paper plants were not located inside of a metropolitan council and in such cases they pose a major threat to the environment, if the effluent should be discharged into the natural environment. This also holds true for the tannery industry and any other industry that was surveyed and located outside of a metropolitan area.

It was also disappointing to have received so little recent data from the South African mining industry in terms of the volumes of effluent produced and the chemical composition of the effluent. However reports of earlier studies were considered (e.g. Pulles et al. & Naicker et al.) and reported on where appropriate. From previous studies it was clear that the mining industry was a major user of water and also produced significant quantities of effluent that may have a negative impact on the environment.

8 CONCLUSIONS

The existing databases were out of date, and of no real value in terms of the requirements for this project.

When considering the total quantity of water used, the industry sector consumed 55%, followed by mining 23% and power generation 20% and then the food industry at 2%. The total effluent production followed a similar trend to usage, with the industry sector at 74%, mining at 10%, food and beverage at 9% and the mining sector at 7%. It is quite obvious that the industry sector accounted for more than 50% of the water used and more than 74% of the effluent produced. In terms of water use, the three leading industries were petroleum (42%), ferrous metals (41%) and pulp and paper (14%). Regarding effluent production, pulp and paper took the lead at 57%, followed by the petroleum industry at 34%. These two industries accounted for more than 90% of the industrial effluent produced.

In terms of water risk analysis, it is obvious that the petroleum industry and the pulp and paper industry potentially poses the greatest risk in the industry sector and in fact overall taking all sectors into account. From the data, mining and power generation and the food and beverage sectors produce similar quantities of wastewater. In terms of risk, based on the chemical composition of the waste, the mining sector poses the greatest potential risk followed by the food and beverage sector and then power generation. The five most important food and beverage groups in terms of water use and effluent production were sugar (27%), poultry (24%), cold drink (17%), breweries (15%) and dairies (10%) in terms of water use, and in terms of effluent production, poultry (31%) followed by cold drinks (20%), breweries (18%), sugar (16%).

Although the electricity generation sector can be considered a major water user in South Africa (accounting for 2% of the total water demand in the country according to the NWRS), the effluent resulting from this sector is minimal, as most of the water evaporates in the coal fired process.

All of the above are significant water users and effluent producers. Due to the lack of detailed information on the effluent composition in most cases, it was difficult to single out specific industries as posing a higher risk than others. Hence the volume (quantity) of wastewater produced should act as a guiding principle in terms of prioritizing research needs.

9 RECOMMENDATIONS

All of the above are significant water users and effluent producers. Due to the lack of detailed information on the effluent composition in most cases, it was difficult to single out specific industries as posing a higher risk than others. Hence the volume (quantity) of wastewater produced should act as a guiding principle in terms of prioritizing research needs. In this respect, a more detailed investigation will need to be conducted in all of the above mentioned industries, to determine the risk and to research mitigation strategies.

Based on the volume of effluent produced, further research should focus on the following industries:

Petroleum Ferrous metals Pulp and paper	74%
Mining	10%
Poultry Breweries Cold drinks Sugar	9%
Power	7%

It is recommended that initiatives be undertaken to improve the data available for these industries and that the database developed as part of this study, be updated accordingly. The availability of data relating to the mining sector in general, especially with regard to effluent production and quality, proved to be an issue of concern. The mining sector is a major water user as well as a major contributor to effluent in South Africa. The fact that much of the effluent resulting from mining activities is often not sent to sewerage plants, but is managed (with differing degrees of success or failure) on site increases the risk posed by this effluent. Therefore, we recommend that a study, focussing specifically on the mining sector, be undertaken in order to collect up-to-date, comprehensive and reliable data so that accurate risk assessments and more relevant recommendations can be made.

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