The development of a toxicity database using freshwater macroinvertebrates, and its application to the protection of South African water resources

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There is a growing international trend towards the protection of freshwater resources from pollution by imposing instream guidelines and specified waste-discharge conditions. Current methods for devising freshwater quality guidelines are based on species sensitivity distributions (SSDs) that are used to identify pollutant concentrations, ensuring the protection of a modelled percentage of species (95% protection is a common goal). SSDs are derived from the toxicity test results of as many taxa as possible for each polluting substance. Waste-discharge licences can be for single substances, specified in terms of chemical concentrations, and derived in conjunction with instream guidelines; or for complex mixtures, specified in terms of toxic units. In both cases toxicity test results are the core data used. The emphasis on SSDs calls into question the species constituting the test populations. It is likely that SSDs based in part on the responses of local organisms will achieve superior site-specific ecological protection. Until the early 1990s, there were very few data on the tolerances of South African freshwater organisms. In the intervening decade, the Unilever Centre for Environmental Water Quality at Rhodes University has developed a toxicity database that, to date, records the responses of 21 South African freshwater taxa to 26 single-substance pollutants or mixtures. This is the most comprehensive database of South African toxicity responses available and has been used in the drawing up of methods and guidelines to protect water resources. This paper aims to make these data available and to describe applications of the data using selected case studies.

Introduction

The South African National Water Act (NWA; No. 36 of 1998)[1] is based on two founding principles: equity, which involves fairness to people now and redressing past inequities; and sustainability, which implies fairness to the environment now and therefore to future generations. In this paper, the focus is on a contribution towards water resource sustainability. In both the White Paper on a National Water Policy for South Africa[2] and the NWA,[1] sustainability is envisaged as the protection of water resources, so that they can be used to the maximum social and economic benefit of South Africans, both now and in the future.

Ecosystems are central to the NWA as it claims explicit jurisdiction over the entire hydrological cycle.[1] Water resources therefore encompass aquatic ecosystems such as rivers, lakes (dams), wetlands, aquifers and estuaries. The NWA designates the national government as the public trustee of water resources and, as such, responsible for both water resource protection and effective use [NWA,[1] chapter 1(3)]. The main tool for water resource protection is the *ecological Reserve.* The policy[2] states in Principle 7: 'The quantity, quality and reliability of water required to maintain ecological functions on which humans depend *shall be reserved* so that human use does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems'. The NWA[1] defines the ecological Reserve as 'the quantity and quality of water required to protect ecosystems in order to secure ecologically sustainable development and use of the relevant resource' [chapter 1(1)(xviii)(b)]. The plan to implement sustainability through resource protection is based on three approaches: water resource classification, resource-directed measures (which include quantified values and descriptions of the ecological Reserve)[3] and source-directed controls.[4,5]

Water resource classification

Water resource classification is the process of classifying the continuum of ecosystem 'health' or integrity. Current thinking envisages categories of ecological integrity ranging from the natural state in 'excellent' condition to a degraded state in a 'poor' condition (Fig. 1). Spatial scales are taken into account in this process. While the spatial scale of water resource *management* occurs at the catchment, or water management area,[6] *classification* occurs at the sub-catchment scale of 'units';[7] for example, a typical riverine unit would be a river reach between an impoundment and the confluence with a large tributary, since below this point water quality and/or ecological health may well change.

The classification of a water resource is an integral part of the resource-directed measures (RDM) process (Fig. 2), which is described clearly and simply in the Department of Water Affairs and Forestry (DWAF) RDM manual.[3] During the analysis of the ecological Reserve (Fig. 2, Step 1), specialist scientists derive quantitative and qualitative instream objectives for flow, water

Excellent	Good		Fair	Poor	Management Classes/
A Minimal	B Slight	C Moderate	D Heavy	E & F Unacceptable	Ecological Categories User impact
Unmodified	Slightly modified	Moderately modified	Considerably modified	Critically modified	Ecological condition

Fig. 1. Diagram of a proposed system of water resource classification. Each ecological category (A–E or Excellent–Poor) is defined by numerical and descriptive objectives termed ecospecs. These are combined with the requirements of users (termed userspecs) into resource quality objectives (RQOs), which define a set of associated management classes. Generally, the use of the A–E classification is restricted to defining environmental categories,[3] whereas the Excellent–Poor nomenclature has been used to define water quality ecospecs[5] as well as to describe management classes that combine both userspecs and ecospecs. The classification system is still being refined.

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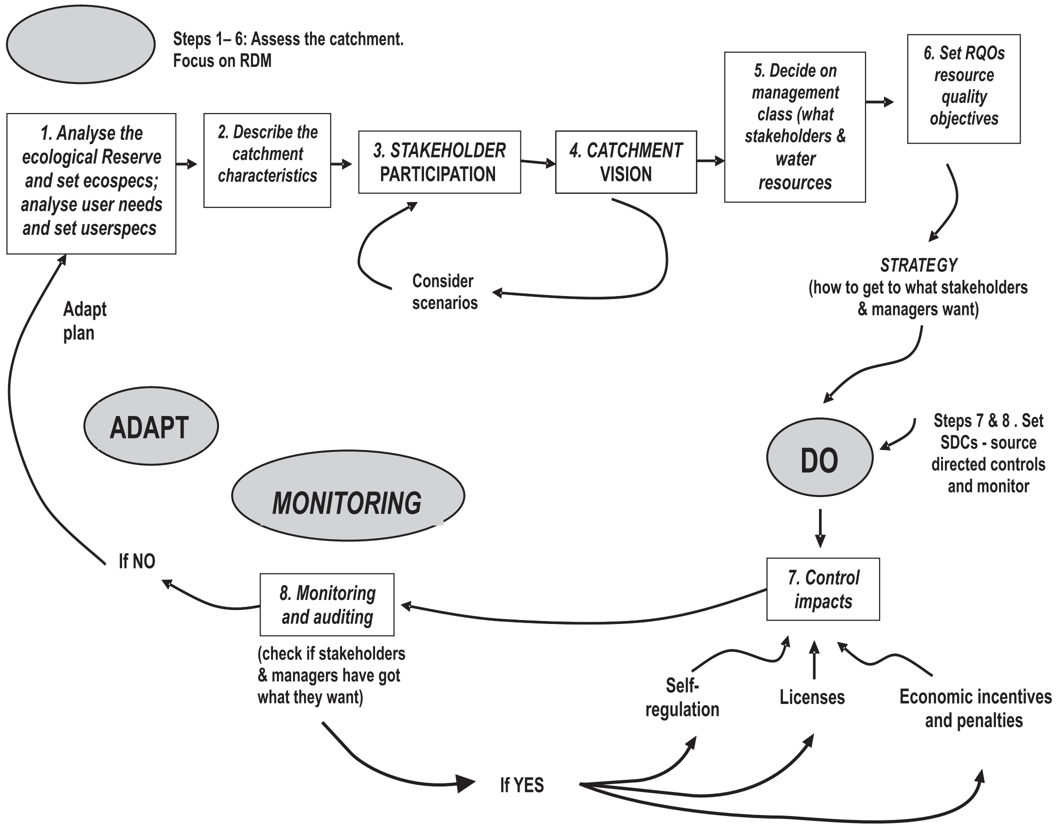

Fig. 2. A proposed strategy for undertaking integrated water resource management (IWRM) from a water quality perspective. Water resource classification (Steps 1 and 5) is an integral part of resource-directed measures (RDMs), which, together with source-directed controls (SDCs), combine to achieve IWRM.

quality variables and biota for each possible ecological category (A–E, or Excellent–Poor) and identify the category which best describes the present ecological status of the resource.[7] The rest of Step 1 involves establishing the quantitative and qualitative requirements of users (for example, tobacco farmers have very specific chloride ion requirements). In Step 3 other water resource factors are described, such as existing impoundments and their flow release regimen or current water quality management plans, for example, the discharge of highly saline water from mines during high flows. During Steps 3 and 4, stakeholders are engaged and the present ecological status is presented to them together with the implications of various scenarios that could make up the vision for the catchment. Catchment characteristics may limit scenario options (for example, there are design limitations in existing impoundments that limit flow options) and generally the management class selected by stakeholders will be the same as, or in an adjacent category to, the present status. Specialist recommendations and stakeholder opinions are taken into account by DWAF (acting on behalf of the minister), and a management class is selected (Fig. 2, Step 5). Each class has specific resource quality objectives associated with it (Fig. 2, Step 6), and these become the management objectives for each unit in the resource.[7]

Resource-directed measures

Resource-directed measures comprise a sequence of activities, undertaken by government, specialists and stakeholders, that focus on the water resource (Fig. 2, Steps 1–6):[3,8]

Step 1: i) Analyse the Reserve (basic human needs Reserve),[9] and the ecological Reserve,[7] and set ecospecs for each resource unit, in each ecological category. (Water quality 'ecospecs' are equivalent to the water quality guidelines drawn up by many countries,[10,11] and the term 'water quality ecospec' can be used interchangeably with 'instream guideline'. An ecospec can be a numerical and/or descriptive objective.[7] In this article, the numerical values for ecospecs are also termed 'boundary values', as they designate a change of ecological condition.)
ii) Analyse user needs and set userspecs. Userspecs articulate user needs. Ecospecs and userspecs are combined into resource quality objectives (RQOs), which define the associated management classes. For example, when a user has a more sensitive flow or water quality requirement than the ecosystem, and if the userspec will not impair the ecosystem's condition, then the userspec becomes the RQO.

Step 2: Describe the catchment characteristics.

Step 3: Engage stakeholder participation.

Step 4: Undertake a 'catchment visioning' process, using scenarios, in a feedback process that includes stakeholders. This action addresses the question: 'Which goods and services do we want from this water resource?'

Step 5: Decide on a management class, and the appropriate RQOs for each resource unit. The final responsibility for selecting the management class for a resource unit lies with government (with contributions from specialists and stakeholders). Each management class has specified objectives and consequently a particular suite of associated goods and services offered by the ecosystem.[8]

Step 6: Develop an implementation strategy to meet RQOs.

Source-directed controls

Source-directed controls (SDC) comprise the management actions required to ensure that the objectives set as part of RDM are met (Fig. 2, Step 7). These include identifying impacts on the resource through its use by either abstraction or waste disposal, and controlling the level of influence through three main mechanisms:

- Self-regulation.
- Licensing abstraction and waste disposal: water users are in the process of moving from the system of abstraction entitled by riparian land ownership to a licensing system (NWA, chapter 4[1,6]). Waste-discharge licences can be for single substances that are specified in terms of chemical concentrations, and are derived in a manner similar to the methods used for ecospecs; and for complex mixtures that are specified in terms of toxicity units.[6,12]
- Economic incentives and penalties: at present most effort goes into licensing but increasingly effective implementation will depend on self-regulation and the use of economic instruments.

Once both RDM and SDC are in place, a monitoring programme should provide feedback on the effectiveness of controlling the consequences of using the water resource, and of meeting RQOs (Fig. 2, Step 8).

Role of ecotoxicity data in classification, RDM and SDC

This paper aims to demonstrate the value of an ecotoxicity database in deriving water quality ecospecs for both RDM and SDC. Within RDM, a core activity is determining the ecological Reserve and deriving ecospecs for each ecological category for flow and for a suite of water quality variables[8,13] including:

system variables: temperature, dissolved oxygen, pH, TSS (total suspended solids),
inorganic salts: sodium chloride, sodium sulphate, calcium chloride, calcium sulphate, magnesium chloride and magnesium sulphate,
nutrients: soluble reactive phosphorus (SRP), total inorganic nitrogen (TIN), and
toxic substances: as listed in the South African aquatic ecosystem guidelines.[14]

Of these variables, the development of ecospecs for salts posed a particular challenge and conditioned the compiling of a South African database on the tolerances, particularly to salts, of local macroinvertebrates (Table 1: only selected data are published in this paper; click here to view the table in its entirety). This paper charts the development of methods for deriving ecospecs for salts and the role of the ecotoxicity database, and then discusses the use of the database in managing complex industrial mixtures.

Salts and salinity

Salinization is recognized as a major threat to water resources in at least South Africa[15,16] and Australia.[17] Many parts of both countries have naturally saline soils, and irrigation return flows in these areas increase the natural salinity of river water.[18] The problem is exacerbated by the discharge of saline industrial and sewage effluents[19] and high rates of evapotranspiration.[16]

Salinity is a general term for the concentration of ions, derived from salts, dissolved in the aquatic environment, and is usually measured as either total dissolved solids (TDS, in mg/l) or electrical conductivity (EC, in mS/m). The ratio of ion concentrations in a water body depends on the salts dissolved during run-off and infiltration, and is affected by catchment geology, soils, and anthropogenic inputs. The 'salinity' of a natural water body is a dominant aspect of the 'chemical signature' of the water quality. Dissolved salts are a natural phenomenon and, generally, guidelines for aquatic ecosystems do not treat salinity as a toxicant, but rather recommend that TDS should not vary by more than a given percentage (usually 15%) from the natural.[10,14]

However, at high concentrations salts are toxicants,[20,21] and different salts and ionic mixtures are differentially toxic.[22,23] Salts commonly found in freshwater systems, in decreasing order of toxicity, are magnesium sulphate, sodium sulphate, calcium chloride, and sodium chloride.[24] This means that bodies of water with the same conductivity but different ionic composition could pose different levels of threat to aquatic ecosystems. Although freshwater guidelines do not currently treat salts as toxicants,[10,11,14] South African ecospecs do, and salt ecospecs for each of the categories have been calculated using toxicity test results.[24] Instream salt concentrations are assessed using a model which converts field-collected water chemistry data on ionic composition to potential salt concentrations, which are then assessed against the ecospecs for salts.[24] We support a slightly different advance in toxicity-based guideline development. This uses both a modification of the Canadian assessment factor method[25] and the Burr Type III statistical distribution method,[26] as described by Warne.[27] South Africa is well placed to adopt the Warne[27] approach, and to apply it on a site-specific basis because of the availability of an extensive database on local salinity tolerances (Table 1) and experience of synthesizing water chemistry, biomonitoring and ecotoxicity information.[8,13]

South African instream water quality guidelines for salinity

Although individual stages in the development of the South African instream salinity guidelines have been documented,[5,13,19,21,24,28–30] the process has not been reviewed in the context of the salt ecotoxicity database (Table 1).

Percentage deviation from 'natural'

In the 1996 South African water quality guidelines for aquatic ecosystems,[14] salinity was classified as a non-toxic inorganic constituent. Guidelines for this category of constituent were given as 'proportional changes from local background conditions', with 15% deviation from natural as the management objective. (It was considered that a deviation of less than 15% would not have any effect on biota.) Consequently, a method was devised for defining the present ecological state of the resource by equating category with a specified percentage deviation from a reference condition.[29] This method was applied in the Olifants River,[19] and indicated that most reaches would be classified in the 'E' or 'Poor' category, with respect to TDS and EC. However, the SASS invertebrate biomonitoring results for the same reaches of the river indicated better categories,[19] suggesting that the percentage deviation method was unsuitable for linking salinity to categories, and that organisms could persist under conditions of elevated salinity.

LC_1 and LC_5 endpoints

An alternative method of relating ecotoxicity endpoints to categories was devised[13] and tested for the Olifants River. This hazard-based approach was based on the premise that tolerances of riverine organisms to salts are affected by their experience of salts in the catchment over evolutionary time, and therefore may be site- or river-specific. The importance of using data derived from tests of indigenous organisms' tolerance of toxicity was emphasized. However, ecotoxicity data were available for few sites, and for the Olifants River the tolerance data for a single taxon, the mayfly, *Tricorythus discolor* (an abundant filter-feeding, riffle-dwelling macroinvertebrate), exposed to sodium sulphate were used because sulphate was a dominant ion in many reaches of the river.[13] However, as the toxicity tests

Table 1. The UCEWQ database: the entries reflect the toxicants and species tested to date (June 1994 – June 2004) using standard protocols.[37] Results reported provide experimental details (organism source, exposure mode, diluent, exposure, duration and number of replicates per experiment) and experimental endpoints (LC_{50} and LC_1). Experimental endpoints are expressed as mg/l nominal concentration per salt (with lower and upper confidence limits LCL and UCL) or % effect concentration per effluent (with LCL and UCL). All statistical analyses were performed using Probit analysis, unless stated otherwise (TSK: trimmed Spearman-Kârber).

Toxicant	Order	Family	Genus	Species	River system*	Mode of exposure	Diluent	Test end-point	Test duration (h)	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
Aquarium salt	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Botha	R	1	M	96	0	50	6916TSK	6094TSK	7849TSK
Aquarium salt	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	96	0	50	24200TSK	22929TSK	25541TSK
Aquarium salt	Hemiptera	Corixidae	*Micronecta*	*piccannini*	Kat	R	1	M	96	0	50	2234	432	3730
Boric acid	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Vaal	R	2	M	96	0	50	538	491	586
Boric acid	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	2	M	96	0	50	1163	896	1873
Boric acid	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	1	M	96	0	50	898	745	1042
Irrigation Kraft effluent	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96	1	50	8.8	0.01	53
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96	0	50	1689	67	14935
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96	0	50	1337TSK	1016TSK	1760TSK
Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Vaal	R		M	96	0	50	6290TSK	5588TSK	7080TSK
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	1	M	96	0	50	6899TSK	6424TSK	7409TSK
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	1	M	96	0	50	7625	6560	8979
Sodium chloride	Ephemerophera	Baetidae	*Baetis*	*harrisoni*	Balfour	R	1	M	96	0	50	1569	0.1	2972
Sodium chloride	Ephemerophera	Baetidae	*Demoreptus*	*natalensis*	Balfour	R	1	M	96	0	50	4370TSK	3493TSK	5466TSK
Sodium chloride	Odonata	Coenagrionidae	*Enallagma*	sp.	Drager Dam	R	1	M	96	0	50	24407TSK	21883TSK	27223TSK
Sodium fluoride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Vaal	R	1	M	96	0	50	71	64	79
Sodium fluoride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	2	M	96	0	50	42	39	45
Sodium sulphate	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Kat	R	1	M	96	0	50	4580TSK	3787TSK	5540TSK
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	96	0	50	2722	1014	4306
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	96	0	50	2584	758	4382
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96	0	50	2757	1875	4409
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96	0	50	2575TSK	2166TSK	3061TSK
Sodium sulphate	Ephemerophera	Baetidae	*Afroptilum*	*sudafricanum*	Palmiet	R	1	M	96	0	50	3096	1952	4087
Sodium sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96	0	50	10379	9940	10808
Sodium sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96	0	50	10320TSK	9908TSK	10749TSK
Sodium sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96	0	50	6363	5994	6695
Sodium sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96	0	50	6303TSK	5968TSK	6657TSK
Sodium sulphate	Ephemerophera	Baetidae	*Afroptilum*	*sudafricanum*	Palmiet	R	1	M	96	0	50	2755	2588	2942
Sodium sulphate	Ephemerophera	Baetidae	*Afroptilum*	*sudafricanum*	Palmiet	R	1	M	96	0	50	2708TSK	2480TSK	2957TSK
Sodium sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96	0	50	8073	7583	8550
Sodium sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96	0	50	7978TSK	7516TSK	8468TSK
Sodium sulphate	Ephemerophera	Baetidae	*Afroptilum*	*sudafricanum*	Palmiet	R	1	M	96	0	50	2382TSK	1910TSK	2969TSK
Sodium sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96	0	50	8598TSK	7805TSK	9472TSK
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	96	0	50	9400	8233	12180
Sodium sulphate	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Kat	R	1	M	96	0	50	5924	4840	7129
Aquarium salt	Hemiptera	Corixidae	*Micronecta*	*piccannini*	Kat	R	1	M	96	0	1	329	4.7	1040
Boric acid	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Vaal	R	2	M	96	0	1	297	222	349
Boric acid	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	2	M	96	0	1	174	84	251
Boric acid	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	1	M	96	0	1	214	121	306
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	1	M	96	0	1	4269	1764	5405
Sodium fluoride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Vaal	R	1	M	96	0	1	29	21	35
Sodium fluoride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	2	M	96	0	1	20	16	24
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	96	0	1	181	3.6	619
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	96	0	1	135	1.3	545
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96	0	1	182	8.0	475
Sodium sulphate	Ephemerophera	Baetidae	*Afroptilum*	*sudafricanum*	Palmiet	R	1	M	96	0	1	1286	117	2006
Sodium sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96	0	1	7115	6083	7803
Sodium sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96	0	1	3865	3209	4352
Sodium sulphate	Ephemerophera	Baetidae	*Afroptilum*	*sudafricanum*	Palmiet	R	1	M	96	0	1	1484	1172	1706
Sodium sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96	0	1	4349	3447	5015
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	96	0	1	4180	1363	5567
Sodium sulphate	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Kat	R	1	M	96	0	1	1182	380	1944

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Table 1 (*continued*)

Toxicant	Order	Family	Genus	Species	River system*	Mode of exposure	Diluent	Test end-point	Test duration (h)	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
Sewage + detergent	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	240	0	50	4.7	0.04	13
Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	240	0	50	466	423	512
Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	240	0	50	455TSK	410TSK	507TSK
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Keurbooms	R	4	M	240	0	50	2212	1770	2619
Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Keurbooms	R	4	M	240	1	50	4002	3466	4452
Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Keurbooms	R	4	M	240	2	50	3523	3047	4002
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	240	2	50	3354	2975	3754
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	240	1	50	2701	1634	4018
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	240	0	50	2767TSK	2219TSK	3450TSK
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240	0	50	3816	2426	4774
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240	0	50	3398TSK	2706TSK	4267TSK
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	240	0	50	839	217	1128
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	240	0	50	757TSK	606TSK	946TSK
Sodium chloride	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	240	1	50	5394	4897	5900
Sodium chloride	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	240	2	50	5905	4181	9534
Sodium chloride	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	240	1	50	5294TSK	4798TSK	5843TSK
Sodium chloride	Ephemerophera	Baetidae	*Baetid*	sp.	Palmiet	R	1	M	240	1	50	3542	2397	4286
Sodium chloride	Ephemerophera	Baetidae	*Baetid*	sp.	Palmiet	R	1	M	240	2	50	3642	3283	4052
Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Bushmens	R	1	M	240	0	50	1770	1466	2094
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Bushmens	R	1	M	240	0	50	5230	4053	6553
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Mooi	R	1	M	240	0	50	3283	1371	11772
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Mooi	R	1	M	240	0	50	3966TSK	3216TSK	4890TSK
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Mooi	R	1	M	240	3	50	2358	1382	3033
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Mooi	R	1	M	240	1	50	1149TSK	923TSK	1430TSK
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Mooi	R	1	M	240	2	50	1784TSK	1444TSK	2204TSK
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Mooi	R	1	M	240	3	50	1413TSK	895TSK	2230TSK
Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Kat	R	1	M	240	0	50	3157	2733	3512
Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Kat	R	1	M	240	0	50	2868TSK	2548TSK	3228TSK
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240	2	50	3429	2295	5384
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240	3	50	4890	3511	6161
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240	1	50	4761TSK	4251TSK	5334TSK
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240	2	50	3456TSK	2986TSK	4000TSK
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240	3	50	4469TSK	3970TSK	5030TSK
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	240	0	50	3167	2744	3444
Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	Mpisini	R	1	M	240	0	50	1752	1522	2006
Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	Mpisini	R	1	M	240	0	50	1765TSK	1492TSK	2088TSK
Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	240	0	50	3149	2755	3511
Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	240	0	50	3249	2349	3685
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	240	0	50	430	347	504
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	240	0	50	414TSK	354TSK	483TSK
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	2	M	216	1	50	1130TSK	963TSK	1326TSK
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	2	M	216	2	50	2292TSK	1949TSK	2695TSK
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	2	M	216	3	50	1823TSK	1534TSK	2167TSK
Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Molenaars	R	2	M	168	0	50	3063	2366	3497
Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Molenaars	R	2	M	168	0	50	2729TSK	2609TSK	2855TSK
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	1	M	168	1	50	1888	849	2464
Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	1	M	168	2	50	906	389	1413
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Breede	R	1	M	168	2	50	5931	4950	6593
Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Breede	R	1	M	168	1	50	13616	2481	50541272
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	252	1	50	1550	1226	1793
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	252	2	50	1715	1427	1935
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	288	0	50	432	342	516
Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	288	0	50	445TSK	390TSK	509TSK

River system: LC = Laboratory culture; Exposure systems: R = recirculating, S = static, S = static with aeration; diluent: 1 = dechlorinated tap water; 2 = river water (same source as test organisms); 3 = reconstituted laboratory water; 4 = rain water; test end-point: M = mortality).
This table includes only a limited selection of data: click here to view the table in its entirety.

Table 2. Specific toxicity endpoints related to environmental categories (resource class boundaries). (Refined and adapted from three ecological Reserve assessments for water quality.[8,13])

Class		Toxicity endpoint
A	Excellent	Lowest measurable 10-day toxicity: < lower 95% confidence limit of the 10-day LC_1
B	Good	Measured 10-day toxicity = 10-day LC_1
C		
D	Fair	Measured 4-day toxicity = 4-day LC_1
E/F	Poor	>4 day LC_1

were of relatively short duration (10 days), measured an extreme biological endpoint (mortality), and only one taxon was tested, the LC_1 and LC_5 values (the 1% and 5% response levels), and their associated confidence limits were used to differentiate categories.[13,30] When instream salinity was assessed by this means, the categories for every reach were consistent with those determined by biomonitoring.[13] With subsequent assessments of the ecological Reserve for the Breede and Thukela rivers, further toxicity tests were undertaken to refine the relationship between salt tolerance endpoints and ecological categories by exposing additional indigenous aquatic invertebrates to sodium chloride.[13] (Experimental salts were selected in the context of local land use. Sodium sulphate was used when industrial and mining impacts were likely, and sodium chloride was the criterion when agricultural salinization was more likely.) The endpoints used to indicate the boundaries of ecological categories, based on the Olifants, Thukela and Breede river assessments, are presented in Table 2.

Toxicologically important major salts method

Subsequently, another South African hazard-based approach, also incorporating toxicity test data, was developed[24] and is currently undergoing refinement. Termed the toxicologically important major salts (TIMS) method, it involves: i) identifying which principal salts are likely to be available in a specific system, ii) calculating lethality (mortality) and sub-lethality (e.g. growth, reproduction) endpoints for specific salts, and iii) using a generic stressor–response relationship (GSRR) function to calculate the boundary values for ecological categories (A–E, or Excellent–Poor).[24]

i) Major salts: the TIMS method is based on the premise that when salts dissolve in water they dissociate into cations and anions. Organisms exposed to such solutions do not physically experience particular salts, but rather a mixture of cations and anions at a specific ratio and concentration.[24] It follows then that a mixture of ions in solution might present itself as a series of toxicologically important major salts, with the possibility of one of the salts never having been introduced into the solution but nevertheless available to the organism because it can be derived from ions present in the solution. The method provides a model for calculating salt concentrations from ionic data.

ii) Endpoint data: the TIMS method[24] differs from the Australian approach,[27] which distinguishes data sets on the basis of exposure, with acute data associated with short-term exposures (up to 96 hours), and chronic data associated with exposures of longer than 96 hours, regardless of endpoint. The TIMS approach takes endpoint as the criterion that categorizes toxicity data.[10,27] Lethality data in relation to exposures of differing durations (less than one hour to several weeks) were therefore compared using an exponential model to project the LC_{50} value to 336 hours; this was termed the threshold LC_{50}.[24] The projected exposure period was adopted because an LC_{50} value decreases with increasing exposure time until a steady state is reached, generally after 240 hours. Sub-lethality data used were no observed effect concentrations (NOECs) with a range of endpoints (immobilization, behaviour, physiological and population).[24] Lethality and sub-lethality benchmark values were then derived by calculating the 5th percentile of the two respective databases, using a non-parametric estimate which accommodated wide confidence intervals.

iii) Generic stressor–response relationship: A GSRR is an expression of a generalized, rather than site-specific, relationship between a stressor, such as salt concentration, and a hazard, such as the likelihood of a loss of species. In the TIMS method, the derived lethality and sub-lethality benchmark values are applied in the GSRR function to produce a hazard value which can be compared to salt ecospec tables. The TIMS method also allows for a site-specific stressor response relationship to be determined and used, instead of the generic stressor–response function, if the water body concerned has special value (pristine or fragile) or evidence exists that biota at the site are likely to be more or less tolerant of the stressor than expected.[24] In this case, the documented responses of indigenous invertebrates to a range of salts found in the Unilever Centre for Environmental Water Quality (UCEWQ) database would provide valuable data.

Species sensitivity distributions (SSDs)

The latest international method being used to derive water quality guidelines involves incorporating data from local and international databases into a distribution method called Burr Type III.[31] This approach has been used to derive the boundary values for toxicants in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality,[10] in order to produce trigger values providing a specified level of protection. In the derivation of guidelines, the Australians use data on chronic conditions or else on acute conditions extrapolated to a chronic state.[27] They also specify 95% species protection as the criterion for toxic substances (but still recognize a 15% deviation from natural for salts). In the case of the South African water quality guidelines proposed for organic toxicants, the percentage species protection advocated for the Excellent/Good boundary is 95%, for the Good/Fair boundary is 90%, and for the Fair/Poor boundary is 80%. In the case of instream guidelines for salinity in South Africa, it is envisaged that the same percentage protection levels will be used to define boundary values for individual salts (but not for salinity expressed as TDS and EC). The process of deriving a new generation of toxicity-based salinity guidelines will draw substantially on the indigenous invertebrate data generated by UCEWQ (Table 1), combined with a large proportion of Australian data on biotic responses and suitable international data.

Complex industrial wastes

Most pollution point sources affect water resources through the discharge of complex mixtures, including wastes from industrial sources as well as effluent from large urban sewage treatment works. The main focal points of SDCs will therefore be through licensing, provision of economic incentives, the imposition of penalties and self-regulation of these waste discharges. The toxicity of industrial waste provides information both for setting instream objectives and licence conditions. Table 1 includes the results of several investigations of complex wastes; the pulp and paper (referred to as irrigation kraft effluent) study will be used as an example.

The main approach to pollution management in South Africa to date, as in many other countries, has been by controlling the concentrations of individual chemical components of mixtures through general and special standards.[32] However, this substance-specific, chemical approach is of limited use in controlling the effects of discharging the complex chemical mixtures because: 1) these mixtures may contain substances that cannot be individually identified; and might be too numerous, too expensive, and/or too difficult, to analyse; 2) some substances may be present in quantities that cannot be detected chemically, but still have an adverse effect; 3) as environmental processes occur, new mixtures can be formed that are either difficult or impossible to characterize; and 4) mixtures can have substantially different environmental effects from the sum of the effects of these substances as individuals.[33] As a further consequence of this, only a limited part of the effects of complex waste discharges observed in water bodies can be explained in terms of chemical analyses of water.

Chemical substance-specific limits or criteria, which are dependent on chemical analysis for enforcement, are therefore of limited use in authorizing and controlling the environmental consequences of the discharge of complex chemical mixtures. The NWA requires of the regulator that the most informative assessments be performed to ensure effective management.[1] On the other hand, dischargers need information about their effluents that allow cost-effective decisions on treatment options. A method that assesses ecological effects in terms of ecotoxicity has been proposed.[12]

The aim of evaluating the ecological effects of complex waste in terms of toxicity is to understand better the combined effect of all the known and unknown hazardous substances in a mixture. It is therefore an effect-specific assessment of the 'whole effluent', in contrast to a measure based on a limited number of substances as it would have been done in a substance-specific approach. In this way, a critical limitation of the substance-specific approach can be overcome.

The recommended approach to the management of complex industrial wastes is the direct estimation of ecological effects potential (DEEEP),[12] which involves the step-wise application of a range of toxicity tests on these wastes. The final stage of this process is a site-specific ecological risk assessment, which is the context in which the UCEWQ approach to the use of wild-caught and laboratory-reared indigenous invertebrates can be applied.

The advantages of toxicity-based assessment of ecological effects include:

- Substances need not be analysed and assessed individually in terms of their ecological hazard.
- Effect parameters provide direct information on the hazard (i.e. the potential for adverse effect) of the mixture.
- The potential for the working of the components of the mixture in combination is included in the effect parameters.
- The effect of unknown substances is included in the effect parameters.
- The method provides valuable information on known substances for which the effects are unknown.
- Since the assessment does not depend on chemical analysis, undetectability of highly toxic substances will not invalidate the assessment, because their influence will be included in the effect parameters.

Disadvantages include:

- A widespread lack of understanding of the use (and usefulness) of ecotoxicity methods, and therefore there is a need for skills training in both the public and private sectors.
- Concerns about cost. Toxicity testing enhances water resource management, and may be less expensive than comprehensive water chemistry analysis, but it will involve additional investment by both the public and private sectors.

Site-specific testing of industrial waste toxicity: a case study

In a study of the effects of mixed waste from a pulp and paper plant in Mpumalanga,[34] the Scherman *et al.* method[13] was used to relate effluent toxicity to a predicted instream category. The paper mill processed 6000 tons of pine and eucalyptus daily. It used of the order of 35 Ml of water and produced 27 Ml of combined effluents daily. These effluents underwent primary treatment, and were then used to irrigate 514 hectares of kikuyu grass pastures. Groundwater in the area between the irrigation fields and the receiving river surfaced at several dolomitic 'eyes', or springs, making it more than usually accessible.

Ecotoxicity tests were conducted, and dilutions of the general effluent, the irrigated effluent, and the groundwater were tested, using the mayfly, *Tricorythus tinctus,* as the test organism. The Scherman *et al.* method[13] was used to relate effluent dilution to the predicted instream category. The results indicated that no more than 2% of effluent concentration should be allowed to enter an A/Excellent category river reach, and between 5% and 6% effluent concentration should be the limit in D/Fair category river reach. Once receiving waters have been classified, these results could be used to set management objectives for resource quality.

Groundwater was demonstrated to have become toxic.[34] To assess the ecological impacts of this, an evaluation of the contribution (as percentage dilution) of the toxic groundwater to river flow would have to be undertaken. An integrated management plan to achieve resource quality objectives would have to take into account the contribution of groundwater to the ecological effects of surface water.

This was an exploratory study, and only data on acute conditions were used. Any application of the results to management should be based on additional data on chronic conditions or extrapolation of results from acute to chronic conditions.[35]

Conclusion

A decade ago, South Africa lacked the expertise to undertake ecotoxicity experiments using wild-caught aquatic organisms, and cultures of indigenous organisms. This paper has shown how toxicity test data can be applied both in the development of water quality guidelines and in managing the impacts of complex industrial waste on aquatic resources. Many of the individual studies which provided the data in Table 1 are still to be published, but with the emergence of SSDs as a preferred method for drawing up guidelines, it is important that the extensive salt tolerance data become available for both national and international use. All the data in Table 1 were generated according to the protocol for the use of wild-caught aquatic invertebrates.[36] The procedure was screened according to the Australian guideline requirements[10] and the UCEWQ data met these exacting standards. The publication of the data on complex waste provides a basis for comparison with future studies and indicates the way forward for the assessment of site-specific risk of industrial effluents.

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Table 1. The UCEWQ database: the entries reflect the toxicants and species tested to date (June 1994–June 2004) using standard protocols.[37] Results reported provide experimental details (organism source, exposure mode, diluent, exposure, duration and number of replicates per experiment) and experimental endpoints (LC_{50} and LC_1). Experimental endpoints are expressed as mg/l nominal concentration per salt (with lower and upper confidence limits LCL and UCL) or % effect concentration per effluent (with LCL and UCL). All statistical analyses were performed using Probit analysis, unless stated otherwise (TSK: trimmed Spearman-Kârber).

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	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
1	Aquarium salt	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Botha	R	1	M	96 (h)	0	50	6916TSK	6094TSK	7849TSK
1	Aquarium salt	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	96 (h)	0	50	24200TSK	22929TSK	25541TSK
1	Aquarium salt	Hemiptera	Corixidae	*Micronecta*	*piccannini*	Kat	R	1	M	96 (h)	0	50	2234	432	3730
1	Boric Acid	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Vaal	R	2	M	96 (h)	0	50	538	491	586
1	Boric Acid	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	2	M	96 (h)	0	50	1163	896	1873
1	Boric Acid	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	1	M	96 (h)	0	50	898	745	1042
1	Irrigation Kraft Effluent	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96 (h)	1	50	8.8	0.01	53
1	Sodium Chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96 (h)	0	50	1689	67	14935
1	Sodium Chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96 (h)	0	50	1337TSK	1016TSK	1760TSK
1	Sodium Chloride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Vaal	R		M	96 (h)	0	50	6290TSK	5588TSK	7080TSK
1	Sodium Chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	1	M	96 (h)	0	50	6899TSK	6424TSK	7409TSK
1	Sodium Chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	1	M	96 (h)	0	50	7625	6560	8979
1	Sodium Chloride	Ephemerophera	Baetidae	*Baetis*	*harrisoni*	Balfour	R	1	M	96 (h)	0	50	1569	0.1	2972
1	Sodium Chloride	Ephemerophera	Baetidae	*Demoreptus*	*natalensis*	Balfour	R	1	M	96 (h)	0	50	4370TSK	3493TSK	5466TSK
1	Sodium Chloride	Odonata	Coenagrionidae	*Enallagma*	sp.	Drager Dam	R	1	M	96 (h)	0	50	24407TSK	21883TSK	27223TSK
1	Sodium Fluoride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Vaal	R	1	M	96 (h)	0	50	71	64	79
1	Sodium Fluoride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	2	M	96 (h)	0	50	42	39	45
1	Sodium Sulphate	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Kat	R	1	M	96 (h)	0	50	4580TSK	3787TSK	5540TSK
1	Sodium Sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	96 (h)	0	50	2722	1014	4306
1	Sodium Sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	96 (h)	0	50	2584	758	4382
1	Sodium Sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96 (h)	0	50	2757	1875	4409

	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
1	Sodium Sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96 (h)	0	50	2575TSK	2166TSK	3061TSK
1	Sodium Sulphate	Ephemerophera	Baetidae	*Afroptilum*	*sudafricanum*	Palmiet	R	1	M	96 (h)	0	50	3096	1952	4087
1	Sodium Sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96 (h)	0	50	10379	9940	10808
1	Sodium Sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96 (h)	0	50	10320TSK	9908TSK	10749TSK
1	Sodium Sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96 (h)	0	50	6363	5994	6695
1	Sodium Sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96 (h)	0	50	6303TSK	5968TSK	6657TSK
1	Sodium Sulphate	Ephemerophera	Baetidae	*Afroptilum*	*sudafricanum*	Palmiet	R	1	M	96 (h)	0	50	2755	2588	2942
1	Sodium Sulphate	Ephemerophera	Baetidae	*Afroptilum*	*sudafricanum*	Palmiet	R	1	M	96 (h)	0	50	2708TSK	2480TSK	2957TSK
1	Sodium Sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96 (h)	0	50	8073	7583	8550
1	Sodium Sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96 (h)	0	50	7978TSK	7516TSK	8468TSK
1	Sodium Sulphate	Ephemerophera	Baetidae	*Afroptilum*	*sudafricanum*	Palmiet	R	1	M	96 (h)	0	50	2382TSK	1910TSK	2969TSK
1	Sodium Sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96 (h)	0	50	8598TSK	7805TSK	9472TSK
1	Sodium Sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	96 (h)	0	50	9400	8233	12180
1	Sodium sulphate	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Kat	R	1	M	96 (h)	0	50	5924	4840	7129
2	Aquarium salt	Hemiptera	Corixidae	*Micronecta*	*piccannini*	Kat	R	1	M	96 (h)	0	1	329	4.7	1040
2	Boric acid	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Vaal	R	2	M	96 (h)	0	1	297	222	349
2	Boric acid	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	2	M	96 (h)	0	1	174	84	251
2	Boric acid	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	1	M	96 (h)	0	1	214	121	306
2	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	1	M	96 (h)	0	1	4269	1764	5405
2	Sodium fluoride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Vaal	R	1	M	96 (h)	0	1	29	21	35
2	Sodium fluoride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Vaal	R	2	M	96 (h)	0	1	20	16	24
2	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	96 (h)	0	1	181	3.6	619
2	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	96 (h)	0	1	135	1.3	545
2	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96 (h)	0	1	182	8.0	475
2	Sodium sulphate	Ephemerophera	Baetidae	*Afroptilum*	*sudafricanum*	Palmiet	R	1	M	96 (h)	0	1	1286	117	2006
2	Sodium sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96 (h)	0	1	7115	6083	7803
2	Sodium sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96 (h)	0	1	3865	3209	4352
2	Sodium sulphate	Ephemerophera	Baetidae	*Afroptilum*	*sudafricanum*	Palmiet	R	1	M	96 (h)	0	1	1484	1172	1706

	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
2	Sodium sulphate	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96 (h)	0	1	4349	3447	5015
2	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	96 (h)	0	1	4180	1363	5567
2	Sodium sulphate	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Kat	R	1	M	96 (h)	0	1	1182	380	1944
3	Sewage + detergent	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	240 (h)	0	50	4.7	0.04	13
3	Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	240 (h)	0	50	466	423	512
3	Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	240 (h)	0	50	455TSK	410TSK	507TSK
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Keurbooms	R	4	M	240 (h)	0	50	2212	1770	2619
3	Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Keurbooms	R	4	M	240 (h)	1	50	4002	3466	4452
3	Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Keurbooms	R	4	M	240 (h)	2	50	3523	3047	4002
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	240 (h)	2	50	3354	2975	3754
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	240 (h)	1	50	2701	1634	4018
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	240 (h)	0	50	2767TSK	2219TSK	3450TSK
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240 (h)	0	50	3816	2426	4774
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240 (h)	0	50	3398TSK	2706TSK	4267TSK
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	240 (h)	0	50	839	217	1128
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	240 (h)	0	50	757TSK	606TSK	946TSK
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	240 (h)	1	50	5394	4897	5900
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	240 (h)	2	50	5905	4181	9534
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	240 (h)	1	50	5294TSK	4798TSK	5843TSK
3	Sodium chloride	Ephemerophera	Baetidae	*Baetid*	sp.	Palmiet	R	1	M	240 (h)	1	50	3542	2397	4286
3	Sodium chloride	Ephemerophera	Baetidae	*Baetid*	sp.	Palmiet	R	1	M	240 (h)	2	50	3642	3283	4052
3	Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Bushmens	R	1	M	240 (h)	0	50	1770	1466	2094
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Bushmens	R	1	M	240 (h)	0	50	5230	4053	6553
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Mooi	R	1	M	240 (h)	0	50	3283	1371	11772
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Mooi	R	1	M	240 (h)	0	50	3966TSK	3216TSK	4890TSK
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Mooi	R	1	M	240 (h)	3	50	2358	1382	3033
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Mooi	R	1	M	240 (h)	1	50	1149TSK	923TSK	1430TSK
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Mooi	R	1	M	240 (h)	2	50	1784TSK	1444TSK	2204TSK

	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Mooi	R	1	M	240 (h)	3	50	1413TSK	895TSK	2230TSK
3	Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Kat	R	1	M	240 (h)	0	50	3157	2733	3512
3	Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Kat	R	1	M	240 (h)	0	50	2868TSK	2548TSK	3228TSK
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240 (h)	2	50	3429	2295	5384
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240 (h)	3	50	4890	3511	6161
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240 (h)	1	50	4761TSK	4251TSK	5334TSK
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240 (h)	2	50	3456TSK	2986TSK	4000TSK
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240 (h)	3	50	4469TSK	3970TSK	5030TSK
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	240 (h)	0	50	3167	2744	3444
3	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	Mpisini	R	1	M	240 (h)	0	50	1752	1522	2006
3	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	Mpisini	R	1	M	240 (h)	0	50	1765TSK	1492TSK	2088TSK
3	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	240 (h)	0	50	3149	2755	3511
3	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	240 (h)	0	50	3249	2349	3685
3	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	240 (h)	0	50	430	347	504
3	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	240 (h)	0	50	414TSK	354TSK	483TSK
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	2	M	216 (h)	1	50	1130TSK	963TSK	1326TSK
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	2	M	216 (h)	2	50	2292TSK	1949TSK	2695TSK
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	2	M	216 (h)	3	50	1823TSK	1534TSK	2167TSK
3	Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Molenaars	R	2	M	168 (h)	0	50	3063	2366	3497
3	Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Molenaars	R	2	M	168 (h)	0	50	2729TSK	2609TSK	2855TSK
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	1	M	168 (h)	1	50	1888	849	2464
3	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	1	M	168 (h)	2	50	906	389	1413
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Breede	R	1	M	168 (h)	2	50	5931	4950	6593
3	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Breede	R	1	M	168 (h)	1	50	13616	2481	50541272
3	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	252 (h)	1	50	1550	1226	1793
3	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	252 (h)	2	50	1715	1427	1935
3	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	288 (h)	0	50	432	342	516
3	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	288 (h)	0	50	445TSK	390TSK	509TSK

	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
4	Sewage + detergent	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	240 (h)	0	1	0.09	0	1.1
4	Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	240 (h)	0	1	244	181	290
4	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Keurbooms	R	4	M	240 (h)	0	1	583	286	868
4	Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Keurbooms	R	4	M	240 (h)	2	1	1314	841	1709
4	Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Keurbooms	R	4	M	240 (h)	1	1	2430	1538	2957
4	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	240 (h)	2	1	1958	1195	2378
4	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	240 (h)	1	1	427	72	875
4	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240 (h)	0	1	1265	198	2128
4	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	240 (h)	0	1	323	7.0	618
4	Sodium chloride	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	240 (h)	2	1	1703	391	2747
4	Sodium chloride	Ephemerophera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	240 (h)	1	1	286	2143	3386
4	Sodium chloride	Ephemerophera	Baetidae	*Baetid*	sp.	Palmiet	R	1	M	240 (h)	1	1	2007	473	2746
4	Sodium chloride	Ephemerophera	Baetidae	*Baetid*	sp.	Palmiet	R	1	M	240 (h)	2	1	2394	1789	2760
4	Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*peringueyi*	Bushmens	R	1	M	240 (h)	0	1	255	138	385
4	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Bushmens	R	1	M	240 (h)	0	1	2716	809	3672
4	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Mooi	R	1	M	240 (h)	0	1	175	0.3	614
4	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Mooi	R	1	M	240 (h)	3	1	817	118	1390
4	Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Kat	R	1	M	240 (h)	0	1	1427	854	1846
4	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240 (h)	3	1	1830	459	2812
4	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240 (h)	2	1	431	64	881
4	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	R	1	M	240 (h)	0	1	1977	1068	2417
4	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	Mpisini	R	1	M	240 (h)	0	1	173	107	246
4	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	240 (h)	0	1	966	586	1301
4	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	240 (h)	0	1	1800	775	2445
4	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	240 (h)	0	1	122	61	179
4	Sodium chloride	Ephemerophera	Heptageniidae	*Afronurus*	*barnardi*	Molenaars	R	2	M	168 (h)	0	1	1564	694	2121
4	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	1	M	168 (h)	1	1	667	68	1214
4	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	1	M	168 (h)	2	1	87	9.0	241

	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
4	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Breede	R	1	M	168 (h)	1	1	13616	2481	50540996
4	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Breede	R	1	M	168 (h)	2	1	3253	1648	4181
4	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	252 (h)	2	1	796	422	1058
4	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	252 (h)	1	1	641	303	901
4	Sodium sulphate	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	288 (h)	0	1	137	74	197
5	Aquarium salt	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	S*	1	M	240 (h)	0	50	7016TSK	6354TSK	7747TSK
5	Sodium chloride	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Kat	S*	1	M	240 (h)	0	50	2786TSK	2584TSK	3005TSK
5	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	S*	1	M	240 (h)	0	50	4744	3959	5422
5	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	S*	1	M	240 (h)	0	50	3012	1163	3992
5	Sodium chloride	Tricladida	Planaria	?	?	Kat	S*	1	M	240 (h)	0	50	5298TSK	4535TSK	6189TSK
5	Sodium sulphate	Tricladida	Planaria	?	?	Kat	S*	1	M	240 (h)	0	50	9177	6821	20188
6	Sodium chloride	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	S*	1	M	240 (h)	0	1	2053	1071	2760
6	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Kat	S*	1	M	240 (h)	0	1	1283	24	2138
6	Sodium sulphate	Tricladida	Planaria	?	?	Kat	S*	1	M	240 (h)	0	1	1161	295	1868
7	Cadmium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	50	0.05	0.02	0.08
7	Cadmium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	50	0.07	0.04	0.1
7	Cadmium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	50	0.09	0.04	0.14
7	Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	50	5979	4823	7059
7	Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	50	5955	5100	6752
7	Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	50	4450	3709	5196
7	Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	50	5487	4528	6446
7	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	50	5989	4874	7181
7	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	50	7002	4710	9024
7	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	50	5734	5084	6614
7	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	50	5477	4840	6007
8	Cadmium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	1	0.005	0.001	0.012
8	Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	1	2167	1082	3055
8	Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	1	1948	1133	2649

	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
8	Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	1	711	359	1086
8	Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	1	1183	596	1764
8	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	1	786	299	1332
8	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	1	2451	433	3963
8	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	1	1783	999	2393
8	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	1	1570	966	2123
9	Aquarium salt	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	S*	1	M	96 (h)	0	50	9314	8188	10075
9	Aquarium salt	Hemiptera	Corixidae	*Micronecta*	*piccannini*	Kat	S*	1	M	96 (h)	0	50	7938TSK	7659TSK	8228TSK
9	Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S*	1	M	96 (h)	0	50	8568	7546	9483
9	Sodium chloride	Ephemerophera	Oligoneuridae	*Oligoneuriopsis*	*lawrencei*	Balfour	S*	1	M	96 (h)	0	50	4815	4300	5244
9	Sodium chloride	Ephemerophera	Baetidae	*Cloeon*	*virgiliae*	Drager Dam	S*	1	M	96 (h)	0	50	4853TSK	4567TSK	5157TSK
9	Sodium chloride	Hemiptera	Pleidae	*Plea*	*pullula*	Drager Dam	S*	1	M	96 (h)	0	50	6741TSK	5218TSK	8709TSK
9	Sodium chloride	Odonata	Coenagrionidae	*Enallagma*	sp.	Drager Dam	S*	1	M	96 (h)	0	50	21608	19433	23531
9	Sodium chloride	Trichoptera	Leptoceridae	Caddisflies	sp.	Drager Dam	S*	1	M	96 (h)	0	50	5621TSK	4427TSK	7136TSK
9	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S*	1	M	96 (h)	0	50	6820	5615	7886
9	Sodium sulphate	Ephemerophera	Baetidae	*Cloeon*	*virgiliae*	Drager Dam	S*	1	M	96 (h)	0	50	3369TSK	2995TSK	3789TSK
9	Sodium sulphate	Hemiptera	Pleidae	*Plea*	*pullula*	Drager Dam	S*	1	M	96 (h)	0	50	9.4	7.1	12
9	Sodium sulphate	Hemiptera	Pleidae	*Plea*	*pullula*	Drager Dam	S*	1	M	96 (h)	0	50	9999TSK	7632TSK	13101TSK
9	Sodium sulphate	Odonata	Coenagrionidae	*Enallagma*	sp.	Drager Dam	S*	1	M	96 (h)	0	50	26224	25025	27365
9	Sodium sulphate	Trichoptera	Leptoceridae	*Caddisflies*	sp.	Drager Dam	S*	1	M	96 (h)	0	50	9803TSK	7968TSK	12061TSK
9	Sodium sulphate	Trichoptera	Leptoceridae	*Caddisflies*	sp.	Drager Dam	S*	1	M	96 (h)	0	50	11345	10555	12343
9	Potassium dichromite	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Botha	S	1	M	96 (h)	1	50	17TSK	12TSK	24TSK
9	Potassium dichromite	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Botha	S	1	M	96 (h)	2	50	17TSK	11TSK	26TSK
9	Potassium dichromite	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Botha	S	1	M	96 (h)	3	50	15TSK	8.6TSK	28TSK
9	Potassium dichromite	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Botha	S	1	M	96 (h)	1	50	9.8TSK	6.3TSK	15TSK
9	Potassium dichromite	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Botha	S	1	M	96 (h)	2	50	9.9TSK	6.3TSK	15TSK
9	Potassium dichromite	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Botha	S	1	M	96 (h)	3	50	14TSK	7.9TSK	24.3TSK
9	Potassium dichromite	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Botha	S	1	M	96 (h)	1	50	4.2TSK	0.6TSK	29TSK

	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
9	Potassium dichromite	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Botha	S	1	M	96 (h)	2	50	8.7TSK	3.5TSK	22TSK
9	Potassium dichromite	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Botha	S	1	M	96 (h)	3	50	8.8TSK	6.0TSK	13TSK
9	Potassium dichromite	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Kubusi	S	1	M	96 (h)	1	50	14TSK	5.8TSK	36TSK
9	Potassium dichromite	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Kubusi	S	1	M	96 (h)	3	50	7.5TSK	3.7TSK	15TSK
10	Sodium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S*	1	M	96 (h)	0	1	5150	3280	6229
10	Sodium chloride	Ephemerophera	Oligoneuridae	*Oligoneuriopsis*	*lawrencei*	Balfour	S*	1	M	96 (h)	0	1	2243	1526	2790
10	Sodium chloride	Odonata	Coenagrionidae	*Enallagma*	sp.	Drager Dam	S*	1	M	96 (h)	0	1	12909	8819	15398
10	Sodium sulphate	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S*	1	M	96 (h)	0	1	2938	1549	3967
10	Sodium sulphate	Hemiptera	Pleidae	*Plea*	*pullula*	Drager Dam	S*	1	M	96 (h)	0	1	2.6	1.0	4.0
10	Sodium sulphate	Odonata	Coenagrionidae	*Enallagma*	sp.	Drager Dam	S*	1	M	96 (h)	0	1	15815	13713	17459
10	Sodium sulphate	Trichoptera	Leptoceridae	Caddisflies	sp.	Drager Dam	S*	1	M	96 (h)	0	1	5727	4638	6548
11	Aquarium salt	Basommatophora	Ancylidae	*Burnupia*	*stenochorias*	Botha	S*	1	M	96 (h)	0	50	7746TSK	-	-
11	Aquarium salt	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	96 (h)	0	1	13310	-	-
11	Aquarium salt	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	R	1	M	96 (h)	0	50	23907	-	-
11	Aquarium salt	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S*	1	M	96 (h)	0	1	6817	-	-
11	Aquarium salt	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S*	1	M	96 (h)	0	50	23009	-	-
11	Aquarium salt	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S*	1	M	96 (h)	0	1	11752	-	-
11	Aquarium salt	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S*	1	M	96 (h)	0	50	24940	-	-
11	Aquarium salt	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	96 (h)	0	1	2622	-	-
11	Aquarium salt	Ephemerophera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	96 (h)	0	50	7527	-	-
11	Aquarium salt	Tricladida	Planaria	?	?.	Kat	S*	1	M	240 (h)	0	50	6490TSK	-	-
11	Cadmium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	1	0.003	-	0.01
11	Cadmium chloride	Decapoda	Atyidae	*Caridina*	*nilotica*	LC	S	1	M	48 (h)	0	1	0.003	-	0.01
11	Irrigation kraft effluent	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96 (h)	1	1	0.3	-	2.6
11	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*tinctus*	Sabie	R	2	M	96 (h)	0	1	45	-	291
11	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	2	M	216 (h)	1	1	103	-	-
11	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Breede	R	2	M	216 (h)	1	50	1130	-	-
11	Sodium chloride	Ephemerophera	Tricorythidae	*Tricorythus*	*discolor*	Mooi	R	1	M	240 (h)	1	1	58	-	451

	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
11	Sodium chloride	Ephemeropthera	Tricorythidae	*Tricorythus*	*discolor*	Mooi	R	1	M	240 (h)	1	50	1277	-	3963
11	Sodium chloride	Ephemeropthera	Tricorythidae	*Tricorythus*	*discolor*	Mooi	R	1	M	240 (h)	2	1	98	-	-
11	Sodium chloride	Ephemeropthera	Tricorythidae	*Tricorythus*	*discolor*	Mooi	R	1	M	240 (h)	2	50	1873	-	-
11	Sodium chloride	Ephemeropthera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240 (h)	1	50	4342	-	-
11	Sodium chloride	Ephemeropthera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	240 (h)	1	1	963	-	-
11	Sodium chloride	Ephemeropthera	Baetidae	*Baetis*	*harrisoni*	Balfour	R	1	M	96 (h)	0	1	215	-	961
11	Sodium chloride	Hemiptera	Pleidae	*Plea*	*pullula*	Drager Dam	S*	1	M	96 (h)	0	1	1	-	-
11	Sodium chloride	Hemiptera	Pleidae	*Plea*	*pullula*	Drager Dam	S*	1	M	96 (h)	0	50	7.6	-	-
11	Sodium chloride	Hemiptera	Pleidae	*Plea*	*pullula*	Drager Dam	R	1	M	96 (h)	0	50	-	-	-
11	Sodium chloride	Hemiptera	Pleidae	*Plea*	*pullula*	Drager Dam	R	1	M	96 (h)	0	1	9.21E+11	-	-
11	Sodium chloride	Hemiptera	Pleidae	*Plea*	*pullula*	Drager Dam	S*	1	M	96 (h)	0	50	-	-	-
11	Sodium chloride	Trichoptera	Leptoceridae	Caddisflies	sp.	Drager Dam	S*	1	M	96 (h)	0	1	3245	-	-
11	Sodium chloride	Trichoptera	Leptoceridae	Caddisflies	sp.	Drager Dam	S*	1	M	96 (h)	0	50	7668	-	-
11	Sodium sulphate	Ephemeropthera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	252 (h)	3	50	2027	-	-
11	Sodium sulphate	Ephemeropthera	Tricorythidae	*Tricorythus*	*discolor*	Olifants	R	1	M	252 (h)	3	1	342	-	-
11	Sodium sulphate	Ephemeropthera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96 (h)	0	50	7736	-	-
11	Sodium sulphate	Ephemeropthera	Leptophlebiidae	*Adenophlebia*	*auriculata*	Palmiet	R	1	M	96 (h)	0	1	2640	-	-
11	Sodium sulphate	Ephemeropthera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	96 (h)	0	1	618	-	-
11	Sodium sulphate	Ephemeropthera	Leptophlebiidae	*Euthraulus*	*elegans*	Kat	R	1	M	96 (h)	0	50	10165	-	-
11	Sodium sulphate	Odonata	Coenagrionidae	*Enallagma*	sp.	Drager Dam	S*	1	M	96 (h)	0	1	7460	-	-
11	Sodium sulphate	Odonata	Coenagrionidae	*Enallagma*	sp.	Drager Dam	S*	1	M	96 (h)	0	50	31703	-	-
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.14	0.13	0.15
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.12	0.11	0.13
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.14	0.13	0.15
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.15	0.14	0.16
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.14	0.13	0.15
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.13	0.12	0.14
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.11	0.09	0.13

	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.11	0.1	0.13
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.12	0.1	0.14
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.18	0.12	0.23
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.18	0.17	0.2
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.26	0.24	0.29
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.22	0.2	0.24
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.22	0.2	0.24
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.17	0.16	0.18
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.18	0.16	0.19
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.12	0.01	0.14
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.26	0.25	0.28
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.24	0.22	0.26
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.24	0.22	0.25
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.15	0.13	0.16
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.2	0.19	0.22
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.2	0.19	0.22
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.28	0.25	0.35
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.2	0.18	0.22
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.17	0.16	0.19
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.19	0.17	0.21
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.17	0.15	0.2
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	1	M	48 (h)	0	50	0.15	0.14	0.16
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.12	0.11	0.13
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.14	0.13	0.15
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.09	0.01	0.13
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.13	0.12	0.15
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.1	0.09	0.12
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.13	0.12	0.15

	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.14	0.13	0.15
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.15	0.13	0.16
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.13	0.12	0.14
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.13	0.12	0.15
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.13	0.11	0.14
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.15	0.14	0.17
12	Detergent	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	42	32	57
12	Potassium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	873	817	930
12	Potassium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	574	0.06	4049
12	Potassium dichromite	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.8TSK	0.6TSK	1.0TSK
12	Potassium dichromite	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	1.6TSK	1.4TSK	1.7TSK
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	1911	426	4490
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	2046TSK	1513TSK	2767TSK
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	2	M	48 (h)	2	50	24771	2337	2611
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	2	M	48 (h)	1	50	2400	2255	2538
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	2926	2868	2989
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	24 (h)	0	50	3827	3670	3979
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	2975	2896	3060
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	24 (h)	0	50	3569	3388	3744
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	24 (h)	0	50	4072	3936	4203
12	Sodium sulphate	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	610	56	10360
12	Sodium sulphate	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	3446	2671	4428
12	Sodium sulphate	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	2565	1218	15874
12	Sodium sulphate	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	3269	2801	3749
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.08	0.06	0.1
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.08	0.05	0.09
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.09	0.07	0.1
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.09	0.07	0.1

	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.08	0.06	0.1
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.08	0.06	0.09
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.04	0.02	0.06
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.04	0.02	0.05
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.05	0.02	0.07
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.12	0.01	0.15
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.11	0.09	0.13
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.11	0.09	0.14
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.12	0.09	0.14
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.11	0.09	0.13
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.09	0.07	0.1
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.1	0.08	0.11
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.17	0.14	0.19
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.13	0.1	0.15
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.17	0.14	0.19
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.08	0.06	0.1
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.11	0.09	0.12
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.1	0.08	0.12
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.12	0.08	0.15
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.08	0.05	0.09
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.09	0.07	0.1
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.1	0.06	0.12
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.07	0.04	0.09
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	1	M	48 (h)	0	1	0.08	0.06	0.1
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.07	0.04	0.08
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.08	0.06	0.09
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.06	0.04	0.08
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.04	0.03	0.06

	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.07	0.05	0.09
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.07	0.05	0.09
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.08	0.06	0.1
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.06	0.04	0.08
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.07	0.05	0.09
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.07	0.05	0.09
12	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.07	0.05	0.09
12	Detergent	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	11	4.0	18
12	Potassium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	586	476	657
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	240	0	754
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	2	M	48 (h)	1	1	1747	1427	1934
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	2	M	48 (h)	2	1	1867	1543	2049
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	2465	2287	2571
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	24 (h)	0	1	3006	2625	3230
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	2533	2293	2658
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	24 (h)	0	1	2517	2131	2768
12	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	24 (h)	0	1	3467	3085	3659
12	Sodium sulphate	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	1425	203	2099
12	Sodium sulphate	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	61	0.5	211
12	Sodium sulphate	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	1663	852	2138
13	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.06	-	0.1
13	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.16	-	-
13	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.3	-	-
13	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.16	-	-
13	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.07	-	-
13	Cadmium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.02	-	0.05
13	Potassium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	76	-	243
13	Potassium dichromite	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	0.7	-	-

	Toxicant	Order	Family	*Genus*	*Species*	River system*	Mode of exposure	Diluent	Test end-point	Test duration	Replicate number	LC	Concentration (mg/l / %)	LCL (mg/l / %)	UCL (mg/l / %)
13	Potassium dichromite	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.04	-	-
13	Potassium dichromite	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	0.3	-	-
13	Potassium dichromite	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	1.4	-	-
13	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	1490	-	-
13	Sodium chloride	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	50	3696	-	-
13	Sodium sulphate	Cladocera	Daphnidae	*Daphnia*	*pulex*	LC	S	3	M	48 (h)	0	1	1.5	-	26

River system: LC = Laboratory culture; Exposure systems: R = recirculating, S = static, S = static with aeration; diluent: 1 = dechlorinated tap water; 2 = river water (same source as test organisms); 3 = reconstituted laboratory water; 4 = rain water; test end-point: M<N>= mortality). This table includes only a limited selection of data; the table is published in its entirety at http://www.sajs.co.za*.