ABSTRACT

The work presented in this thesis stemmed out of the apparent lack of a method for incorporating salinity effects into environmental life cycle assessments. Salination of the water resources is a well-known problem in South Africa, and is of strategic concern. Any environmental decision support tool that does not allow the evaluation of salinity effects therefore has limited applicability in the South African context. The starting-point for the work presented in this thesis was to evaluate existing impact categories, and the characterisation models used to calculate equivalency factors for these impact categories, in an attempt to incorporate salinity effects into existing categories and/or characterisation models. The types of effects that elevated (above normal background levels) dissolved salt concentrations have on the natural and man-made environment were evaluated, and it was concluded that, although there was some overlap with existing impact categories, some of the salinity effects could not be described by existing impact categories. It was also concluded that there are clear and quantifiable causal relationships between releases to the environment and salinity effects. A separate salinity impact category was therefore recommended that includes all salinity effects, including; aquatic ecotoxicity effects, damage to man-made environment, loss of agricultural production (livestock and crops), aesthetic effects and effects to terrestrial fauna and flora. Damage to the man-made environment is evaluated in terms of effects on equipment and structures, interference with processes, product quality and complexity of waste treatment, and is used as an indicator for the environmental consequences derived from the caused additional activity in the man-made environment. Once a conceptual model for a separate salinity impact category had been formulated, existing characterisation models were evaluated to determine their applicability for modelling salinity effects. Salination is a global problem, but generally restricted to local or regional areas, and in order to characterise salinity effects, an environmental fate model would be required in order to estimate salt concentrations in the various compartments, particularly surface and subsurface water. A well-known environmental fate and effect model was evaluated to determine if it could be used either as is, or in modified form to calculate salinity potentials for LCA. It was however concluded that the model is not suitable for the calculation of salinity potentials, and it was therefore decided to develop an environmental fate model that would overcome the limitations of existing model, in terms of modelling the movement of salts in the environment. In terms of spatial differentiation, the same approach that was adopted in the existing model was adopted in developing an environmental fate model for South African conditions. This was done by defining a "unit South African catchment" (including the air volume above the catchment), which consists of an urban surface; rural agricultural soil (and associated soil moisture); rural natural soil (and associated moisture), groundwater (natural and agricultural) and one river with a flow equal to the

sum of the flows of all rivers in South Africa, and a concentration equal to the average concentration of each river in the country. A non steady-state environmental fate model (or, hydrosalinity model) was developed that can predict environmental concentrations at a daily time-step in all the compartments relevant to the calculation of salinity potentials. The environmental fate model includes all the major processes governing the distribution of common ions (sodium, calcium, magnesium, sulphate, chloride and bicarbonate) in the various compartments, and described as total dissolved salts.

The effect factors used in the characterisation model were based on the target water quality ranges given by the South African Water Quality Guidelines in order to calculate salinity potentials. The total salinity potential is made up of a number of salinity effects potentials, including; damage to man-made environment, aquatic ecotoxicity effects, damage to man-made environment, loss of agricultural production (livestock and crops), aesthetic effects and effects to terrestrial fauna and flora. The total salinity potentials for emissions into the various initial release compartments are shown in the table below.

Initial release compartment	**Total salinity potential (kg TDS equ./kg)**
Atmosphere	0.013
River	0.16
Rural natural surface	0.03
Rural agricultural surface	1.00

The salinity potentials are only relevant to South African conditions, and their use in LCA in other countries may not be applicable. This, in effect, means that the life cycle activities that generate salts should be within the borders of South Africa. It has been recognised that the LCA methodology requires greater spatial differentiation. Salination is a global problem, but generally restricted to local or regional areas on the globe, and it is foreseen that local or regional salinity potentials would need to be calculated for different areas of the earth where salinity is a problem. The LCA practitioner would then need to know something about the spatial distribution of LCA activities in order to apply the relevant salinity potentials. The LCA practitioner should also take care when applying the salinity potentials to prevent double accounting for certain impacts. Currently, this is simple because no equivalency factors exist for common ions, or for total dissolved salts as a lumped parameter.

The distribution of salinity potentials, which make up the total salinity potential, appears to be supported by the environmental policies and legislation of South Africa, in which irrigation using saline water is listed as a controlled activity, and subject to certain conditions.

The major recommendations regarding further work are focussed on the collection of data that will allow further refinement of the model, and to decrease the uncertainty and variability associated with the results. The values of the published equivalency factors are dependent on the mathematical definition of the local or regional environment, and these values have been calculated for Western European conditions. Equivalency factors may vary by several orders of magnitude, depending on how the local or regional conditions have been defined. It is therefore recommended that the model developed in this work ultimately be included into a global nested model that can be used to calculate equivalency factors for other compounds, including heavy metals and organic compounds. This would result in equivalency factors for all compounds that are relevant to South Africa.