AN INVESTIGATION INTO THE QUALITY OF WATER FOR ANIMAL PRODUCTION

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EXECUTIVE SUMMARY

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CONTENTS

BACKGROUND AND MOTIVATION

- According to information from the Directorate of Soil Conservation and Drilling Services (Department of Agriculture), a total of 4 085 boreholes were sunk in a region between Venda to Gordonia. Of 1 267 holes sunk by the state, 402 were successful, but 26 were of unacceptably poor quality judged by the present standards. Some waters were certified acceptable for ruminant, but not for human or monogastric consumption. Of 2 818 private boreholes sunk, 844 were successful in yielding water, but 25 were classified unfit for human and animal consumption.

- There are principally two sets of water quality guidelines for livestock in use in South Africa, namely, the Summarised Water Quality Variables for Livestock as published by the Department of Environmental Affairs (Kempster, Hattingh and van Vliet, 1985), and those proposed by Adelaar, (1974). The former guidelines are based on international guidelines, whilst the latter are presently used by Namibia, the Directorate for Soil Conservation and Drilling Services (Department of Agriculture , not only for classifying water fit or unfit for use for livestock, but also for declaring a borehole successful or not-successful.

- Both sets of guidelines do not offer solutions for areas which have inherently saline waters (found in Venda and Gordonia), nor do they take into account the synergistic and antagonistic factors that affect the tolerance levels and subsequent production of livestock. As this scenario presents itself frequently in the arid zones of southern Africa the need to assess accurately the impact of a water source for a given environment on a given livestock production system consequently arises.

- The current water quality guidelines are based largely on assumptions as yet untested in the South African context owing to a lack of locally established guidelines. Verified standards of water quality for animal production which enable accurate assessment of water quality are self-explanatory in terms of animal health and performance and the viability of treating sub-standard water sources.

• ORIGINAL OBJECTIVES

· AIM

The original aim of the project was to determine standards of acceptability (minimum and maximum) of water quality for animal production, which may be applicable to subterranean and other water sources.

· PROGRAMME

Phase 1:

(1) a comprehensive and ongoing literature study from a computerised data base on water quality, the physiological responses of fodder plants, ruminal bacteria and livestock to organic and inorganic contaminants;

(2) a literature study of geological, industrial and other factors affecting water quality;

(3) determining water quality in a sampling survey of boreholes in the Venda to Gordonia region, both within, on the perimeter, and outside the perimeter of the Transvaal geological depression;

(4) studying the results and formulating research proposals for the following phase;

(5) selecting appropriate research stations for proposed experiments;

(6) negotiate with potential co-researching institutions;

(7) re-evaluate and finalise proposed experiments;

(8) report progress.

· Phase 1 was defined as an exploratory research phase to determine if the biological assays proposed for Phases 2 and 3 were necessary.

· Phase 2 (Jun 91 - Jun 93) - Biological assays.

· Phase 3 (Jul 93 - Dec 93) - Compilation of quality norms for water intended for animal production.

- REVISED OBJECTIVES FOLLOWING THE COMPLETION OF PHASE 1

  Based on the following results of Phase 1 (review of geohydrological data on subterranean water and literature review), revised objectives were proposed:

  Results of Phase 1:

  - verification of the guidelines (Kempster, *et al.*, 1985; and Adelaar, 1974) was needed as many water quality variables recorded levels which yielded differing classifications for livestock dependant on the guideline used in the assessment;
  - verification of all the water quality variables was not practically possible, rather specific water quality variables relevant to southern Africa should form the focus of the research;
  - the guidelines in their current format (single values for a specific water quality variable in the form of a maximum permissable level) are inadequate in assessing the impact of a water source on livestock production;

  Revised objectives:

  (1) point (4) in the Original Objectives was beyond the scope of the project and is being addressed by the Department of Water Affairs and Forestry.

  (2) research be focused on the water quality variables fluoride, total dissolved solids, chloride, sulphate and nitrate, with additions to the list dependant on in-coming water quality monitoring data;

  (3) the area of research be expanded from the regions Venda and Gordonia to encompass the entire southern Africa;

  (4) research be conducted with the aim of developing a Water Quality Index System which could take into account the significant factors affecting the effect of a given water source on a given livestock production system;

  (5) the WRC be provided with Interim Water Quality Guidelines, incorporating as much current research findings as practically possible, for use until such time as a Water Quality Index System is complete.

SUMMARY OF MAJOR RESULTS

- REVIEW OF LITERATURE AND WATER QUALITY DATA
- BIOLOGICAL ASSAYS
- WATER QUALITY INDEX SYSTEM

- Guideline levels for water quality variables and the specific variables considered to be relevant differ between countries and emphasize the need for each country to have own relevant variables and levels of acceptability.

- Research regarding water quality variable levels of acceptability for livestock drinking water for southern Africa is needed, mainly as the present levels are based largely on assumptions as yet untested in the southern African context owing to a lack of locally established guidelines.

- The need for and importance of ground water as a water source is increasing.

- The water quality variables fluoride, total dissolved solids, chloride and sulphate were identified as the variables of main concern based on their incidence of potential toxicity in the designated region (NW & NE Transvaal and NW Cape), and the variables fluoride, total dissolved solids, chloride, sulphate and nitrate in the entire southern African region.

- The present system of assessing the suitability of water for livestock appears to be inadequate, largely as a result of its lack to account for the following factors:

- They do not offer any solution for areas which have inherently saline waters with water quality variable concentration in excess of the recommended maximum limits;
- They do not take into account, to a large enough extent, the differing water quality requirements, in terms of quality and quantity, of animals due to the following factors:
  - species tolerances;
  - the climatic effect on the animal (macro - and microclimates);
  - the feed environment;
  - the production system;
  - the animal's physiology;
  - the animal's production stage;
  - the effect of time exposure to the potentially hazardous substances;
  - the effect of a concentrated intake over a short period;
  - the physiological effect of exposure to potentially hazardous elements;
  - the economic implications of such exposure for different production systems and production conditions;
  - the probable carry-over effect of potentially toxic substances to the user of the animal product after a limited exposure (growth to market weight);
  - the synergistic and antagonistic interactions between water quality variables, and water quality variables and the environments;
  - the actual real ingestion of a water quality variable.

- The aforementioned has the following implications:

- A given water source can be fit or unfit for livestock watering depending on the intended use of the water source and the conditions attached to that use;

- As the scenario of inherently saline waters with water quality variables in excess of the recommended limits presents itself frequently in the arid zones of southern Africa, the need to accurately assess the effect of a water source for a given environment on a given livestock production system consequently arises;

- Using the current guidelines, water which may be fit for livestock watering is classed as unfit, and water that may have an adverse effect on livestock production is classed as fit for livestock watering. Both imply that the optimal utilisation of water may not be occurring due to the inaccuracies of the current guidelines.

- EFFECT OF FLUORIDE IN THE DRINKING WATER

A SHEEP

(1) The effect of F in the drinking water on the growth and health of South African Mutton Merino (SAMM) wethers:

· The growth and health of SAMM wethers to market weight (live weight 23 ± 4.1 kg to 41.9 ± 3.5 kg for 107 days) was not adversely affected by NaF in the drinking water to a level of 20 mg/l F or an ingestion of 96 mg F/ sheep/ day (live weight 25 kg) and 122 mg F/ sheep/ day (live weight 45 kg).

(2) Fluoride in the drinking water at a level of 15 mg/l did not adversely affect the growth or health of South African Mutton Merino wethers over a 105 day exposure period.

B CATTLE

(1) Effect of F in the drinking water on growth and health of Bonsmara steers:

· The growth and health of Bonsmara steers to market weight (live weight 198.39 ± 17.47 kg to 359 ± 17.2 kg for 124 days) was not adversely affected by NaF in the drinking water to a level of 20 mg/l F or an ingestion of 350 mg F/ steer/ day (live weight 200 - 250 kg) and 600 mg F/ steer/ day (live weight 250 - 350 kg).

C POULTRY

(1) Effect of F in the drinking water on growth and health of Ross broiler hens:

· Fluoride was found to have a positive effect on weight gain and feed intake, and no adverse effects on growth and health to slaughter weight (49 days).

C **POULTRY** (cont.)

(2) Effect of F in the drinking water on Silver Grey Hy-line layers:

- There were no significant differences between treatments regarding feed and water intake, weight gain, feed conversion and liver weights. No significant differences occured between treatments regarding the breaking strength of the eggs or egg production (weeks 19 - 74). The results indicate that F up to a level of 20 mg/l in the drinking water, had no adverse effect on production characteristics or health over a 74 week production period.

- MAJOR CONCLUSIONS

- The results of these studies offer a new approach to the evaluation of a water source and assessing its effect on livestock as it provides a basis of true variable exposure determination which allows for the incorporation of a number of crucial synergistic and antagonistic factors such as production system, species and type, time exposure, climatic, nutritional and physiological stage factors which singularly or cumulatively affect the water intake and metabolic effects the water quality variable exerts on the animal.

- The total ingestion, in terms of quantity and time, of a potentially hazardous water quality variable is the crucial factor in determining the levels of acceptability for water quality variables.

• EFFECTS OF VARIOUS SALTS IN THE DRINKING WATER

A SHEEP

(1) The effects of chloride and sulphate salts in the drinking water on water intake in SAMM wethers:

- Palatability:
  - Chloride was found to significantly reduce water and feed intake at a Cl:TDS ratio of 0.57 (TDS = 22 425 mg/l).
  - The SO_4 treatment did not yield a significant increase in water intake with increasing TDS levels, suggesting a negative palatability effect.
  - An increase in the Cl:TDS ratio to 0.608 (constant TDS level of 16500 mg/l) was accompanied by a significant decrease in water intake compared with ratios of 0.44 and 0.196.
  - Decreasing the ratio of Cl:TDS and SO_4:TDS with a constant TDS level did not significantly alter water intake response.

- Growth and health
  - No adverse effects were found for growth or health over a 105 day exposure period to salinity levels in excess of the current guidelines, indicating the ability of the animals to adapt to saline water with slow incremental saline treatment increases.

- Saline - Fluoride interaction:
  - A strong significant negative correlation was found between increase in salinity of the drinking water and bone F concentration (metacarpal bone).

B CATTLE

(1) The effect of various levels of chloride and sulphate salts in the drinking water at various TDS levels on the palatability of water for Friesland steers:

- Increasing concentrations:
  - Sulphate concentrations were tolerated until a level of 5 666 mg/l SO_4 (TDS = 8 332 mg/l), where a significant decrease in water intake occurred.
  - Chloride concentrations were tolerated until a level of 7 800 mg/l Cl (TDS = 13 000 mg/l), where a significant decrease in water intake occurred.

- Ratio manipulations:
  - TDS = 6 000 mg/l:

    A SO_4:TDS ratio of 0.5 was the upper limit of reasonable risk and a greater ratio would probably result in decreased water intakes. Ratios less than 0.5, would probably not result in decreased water intakes (with brief adaptation).
  - The maximum Cl:TDS ratio of 0.6 would probably not result in a decrease in water intake (following a brief adaptation to saline waters).

  - TDS = 10 000 mg/l:
  - The upper limit of reasonable risk would appear to be at a lower SO_4:TDS ratio of 0.3.
  - The Cl:TDS ratio of 0.6 would probably not result in an adverse effect on water intake (following a brief adaptation period).

  - TDS = 13 000 mg/l:
  - The upper limit of reasonable risk would appear to be at a lower SO_4:TDS ratio of 0.153.
  - The Cl:TDS ratio of 0.6 would appear to be the upper limit of reasonable risk. A ratio of 0.5 and less would be recommended for this TDS level.

- EFFECTS OF VARIOUS SALTS IN THE DRINKING WATER - general conclusions for sheep and cattle

- Specific Cl:SO_4:TDS ratios have different effects on the palatability of water for varying and constant TDS levels.

- The ratio of SO_4:TDS at which an adverse effect on palatability can be expected decreases as the TDS level increases.

- The philosophy that at different TDS levels, different ratios of Cl and SO_4 to TDS are acceptable, would seem to be correct.

- As the ratio moves away from the zone of preference (Figure 1) the following occurs:
  - the risk of an adverse effect on palatability (and hence production) occurring increases;
  - the importance of a slow, small incremental adaptation period becomes greater;
  - management of the water source becomes more critical; and
  - synergistic and antagonistic factors become more important as a method of utilizing the water source optimally (ie. nutritional status, water demand due to physiological stage and production requirements).

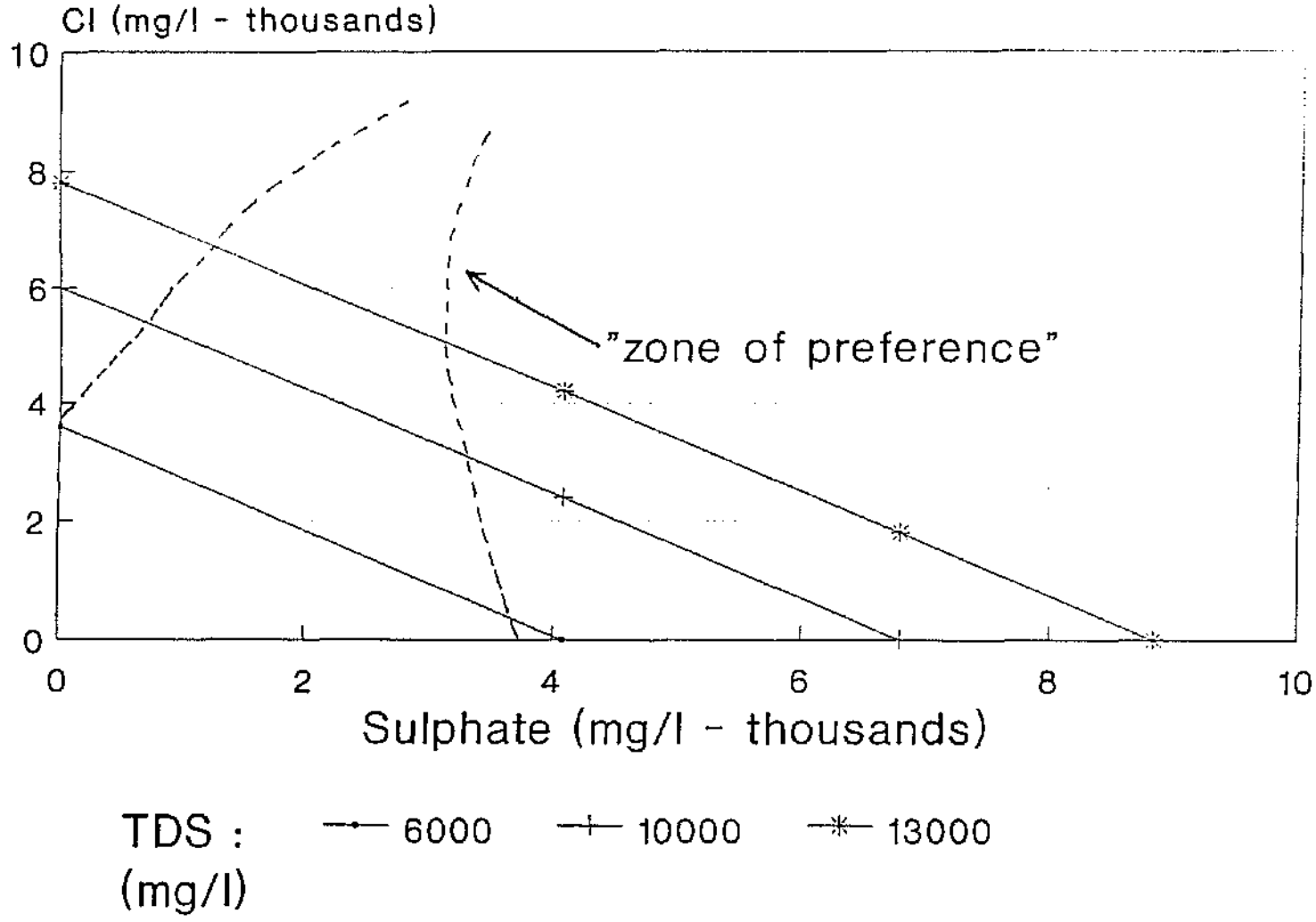


Figure 1 Theoretical position of the "zone of preference"

- EFFECTS OF VARIOUS SALTS IN THE DRINKING WATER

- MAJOR CONCLUSIONS

· Knowledge of the palatability of a water source is important in classifying a water source as fit for use or not fit for use, not only for predicting a decline in water intake, but also for attempting to estimate possible solutions and risks involved with highly saline waters. The use of a "zone of preference" in a guideline system using the three water quality variables with a high incidence of potentially hazardous levels, namely TDS, Cl and SO_4, is a more accurate method of predicting the effect of a water source on livestock and offering possible solutions to water sources with high concentrations of these variables.

· Although the results from these studies are in terms of the specific values and TDS levels, species specific, the rationale behind the results would appear to be valid, and therefore find application for livestock in general.

- BRIEF DESCRIPTION

- The results of the research conducted culminated in the envisaged formation of a Water Quality Guideline Index System (WQGIS) for livestock watering with reference chiefly to subterranean water sources and primary associated variables.

- The WQGIS will cater for primarily two scenarios, namely variables that are potentially hazardous and those that affect the palatability of the water for livestock.

- At various stages in the arrival of a combined index for the two scenarios important factors that influence the impact of the water source together with the relevant environment and livestock production system will be taken into account.

- The design is to cater for a multidisciplinary approach. In doing this, the system becomes a new process which incorporates knowledge from other specialised fields that involve animal production.

- In this integration the system sets itself apart from existing guidelines in that it will more accurately assess the impact of a water source in a given environment and livestock production system.

- The system should also lend itself to provide answers for different users, depending on the amount of information available. The more information available, the more accurate the assessment. In this respect the system will be flexible, depending on the needs and capabilities of the users.

- The WQGIS will be in the form of a software package that can cater for continual addition and incorporation of new information as it becomes available.

- BRIEF DESCRIPTION (Cont.)

· Application of the system should be found by institutions, organisations and persons that are involved in any way in receiving water samples and decision making regarding the use of the water source for livestock drinking purposes.

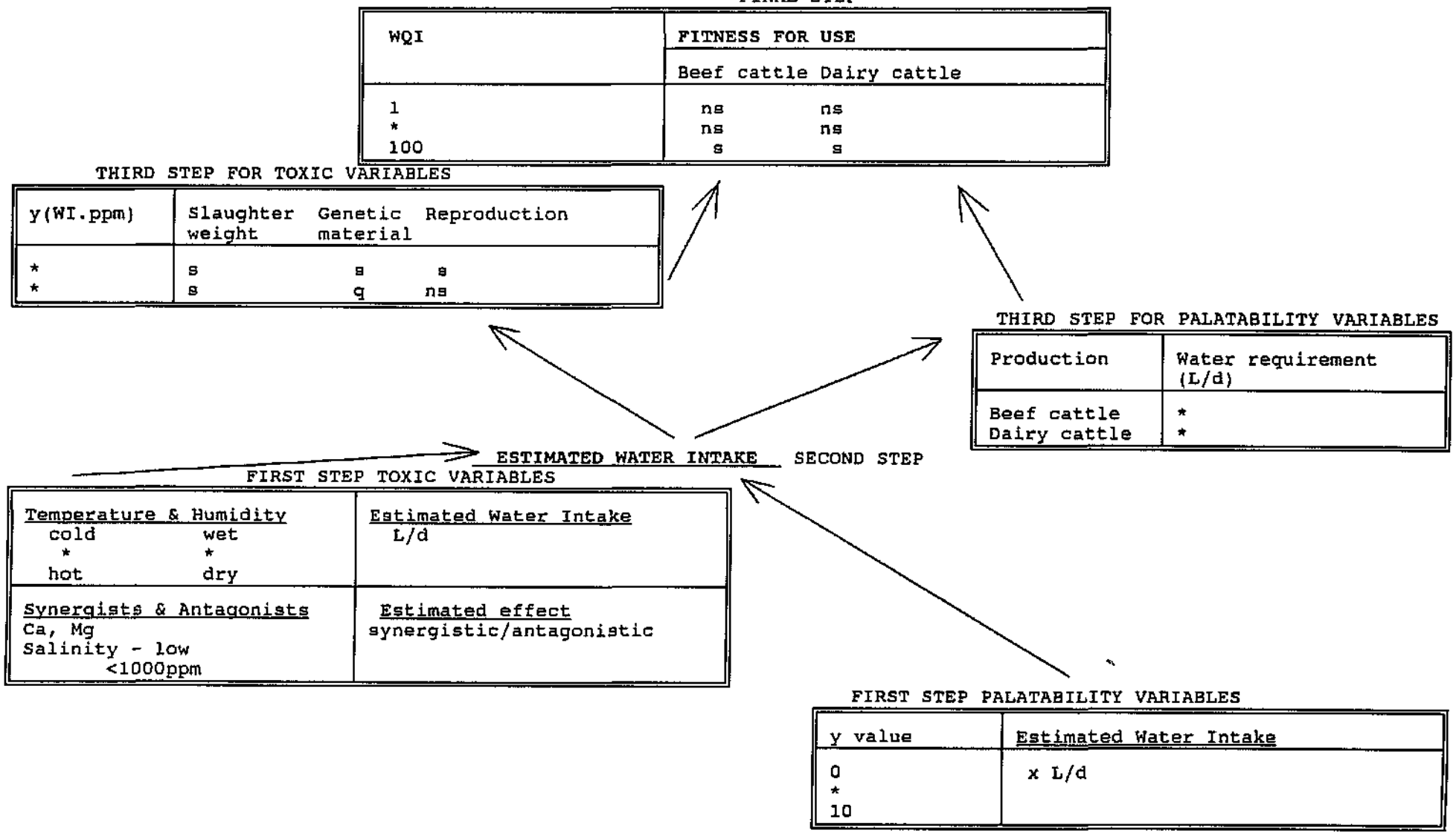
· A brief outline of the WQGIS is presented in Figure 2.

- MAJOR CONCLUSIONS

· The formulation of a Water Quality Guideline Index System (WQGIS) that caters for potentially hazardous variables and variables which affect the palatability of water for livestock is envisaged, which will adequately assess the suitability of water for livestock for a given livestock production system.

· There is a need for a water quality monitoring system that monitors ground water quality so that recent, statistically reliable data can be used to formulate a WQGIS. The WRC Report No: 482/1/93 by Parsons and Tredoux, (1993) describes the establishment of a national groundwater quality monitoring programme.

Figure 2 Schematic representation of index system.



- PURPOSE

- Interim water quality guidelines (WRC Report No: TT 65/95) were developed to provide a quick reference for water quality guidelines for livestock watering, as much as is presently practical, that incorporate current research findings relevant to southern African conditions.

- The interim guidelines are for use until such time as a WQGIS is completed.

EVALUATION

- Extent to which contract objectives have been reached:

The primary objective of evaluating the validity of the present guidelines has been successfully achieved. The results emanating from the research conducted has provided a new approach to water quality guidelines for livestock, and in so doing achieved the objective of determining the factors involved in the acceptability of water for livestock watering. The interim water quality guidelines developed incorporate as much of the project findings as possible. The project objectives progressed from determining the validity of current guidelines and levels of acceptability, to formulating a proposed WQGIS that will also provide possible solutions for poor quality water sources, and in so doing optimalise the utilisation of southern African water sources.

- The report offers the user:
  - a new approach to water quality guidelines in general; and
  - interim water quality guidelines for livestock watering until such time as a WQGIS is developed.

- Actions to be taken as a result of the findings:
  - use the interim guidelines developed for livestock watering
  - continue to develop a WQGIS.

• FURTHER RESEARCH

- A water quality monitoring system is recommended that is on-going to verify the status of water quality variables.

- Further research is recommended to identify:
  - the main types of livestock production systems and the water source common to them;
  - the main variables of relevance in these water sources and their effect on livestock.

- Further research is recommended to develop guideline levels for the respective livestock production systems and important water quality variables in the format of an index system.

REFERENCES

Adelaar, T.F. (1974). Veeartsnykunde Onderstepoort (Reuter & Gous), 1974).

Casey, N.H., Meyer, J.A. and van Niekerk, W.A. (1994). Interim water quality guidelines for livestock watering. WRC Report No: TT 65/94. ISBN: 1 86845 083 X.

Kempster, P.L., Hattingh W.H.J. and van Vliet, H. R. (1985). Summarized Water Quality Criteria. Department of Environmental Affairs. Hydrological Research Institute. Technical Report No. TR 108.

Parsons, R and Tredoux, G., (1993). The development of a strategy to monitor groundwater quality on a national scale. WRC Report No: 482/1/93. ISBN: 1 86845 019 8.