Information Sheet

5.12 Irrigation water quality for sustaining soil health and sugarcane yield

Poor irrigation water quality, particularly salt-affected sources, can cause soil degradation. This can induce crop stress and ultimately result in a decline in crop yield, while chemical and biological contaminants can have negative impacts on crop performance. To keep soil degradation to a minimum and sustain crop yields, monitor irrigation water quality regularly Excessive amounts of soluble salts (salinity) can cause an increase in soil salt content, while unfavourable sodium (Na) levels can also lead to sodic soil conditions (For more detail on saline/sodic soil conditions consult SASRI's **Information Sheet 5.11** and **Chapter 10** in "**Understanding and managing soils in the South African sugar industry**" handbook – both available at www.sasri.org.za).

This information sheet highlights key considerations of irrigation water quality in relation to its impact on soil health and crop performance, guiding correct water sampling and interpretation of these results according to SASRI's Fertiliser Advisory Service (FAS).

FAS provides a basic water quality assessment for **salinity** (excessive salt) and **sodicity** risk (excessive sodium (Na) in relation to calcium (Ca) and magnesium (Mg)) that includes measures of:

- pH,
- base cations (Ca, Mg, potassium (K) and Na),
- alkalinity (HCO_3),
- electrical conductivity (EC),
- sodium adsorption ratio (SAR),
- adjusted SAR (ASAR), and
- effective EC (EEC).

Irrigation water sources in the South African sugar industry

Generally, irrigation water is sourced from rivers, dams, ponds or boreholes. The major rivers that are utilised for sugarcane irrigation are the Crocodile, Lomati and Komati Rivers in Mpumalanga, and the Pongola, Bivane, Umfolozi, Mkuze and Umhlatuze Rivers in KwaZulu-Natal. The water quality of these rivers is fair to good, though the Mkuze and Pongola Rivers sometimes contain moderate to high levels of soluble salts (notably Ca, Mg and Na) during periods of low flow. Past studies have shown that water quality is deteriorating over time due to erosion, non-point source pollution and periodic contamination spills. Dams and ponds are constructed on farms for the purpose of water storage. The quality of water in these dams will be dependent on the source water (e.g. rivers, rainfall) and on-farm recycling from drainage lines, which may vary seasonally. Where suitable aquifers and high water tables are present, boreholes may be drilled to supply irrigation water. However, as for other water sources, the quality of borehole water will depend on the quality of the water that feeds the aquifer and also requires monitoring to ensure that the quality is acceptable.

Water quality categories

Water quality is divided into three broad categories:

1) Physical quality - presence of suspended particles (e.g. sand, silt, clay, organic particulates).

2) Biological quality – occurrence of organics, pathogens, algae, biological oxygen demand.

3) Chemical quality - pH, dissolved salts and organics, toxic elements and compounds, chemical oxygen demand.

Table 1 describes properties reported in the routine water quality testing by SASRI-FAS and Table 2 outlines additional water quality parameters that require consideration in some instances.

1. Physical Quality

Physical properties of water are usually referred to as suspended particles (which include sand, silt clay, algae, plant material or organic particulates) that can impact irrigation system performance and may require filtration to prevent blockages and damage in irrigation systems. From a soil health and crop quality perspective, their effect tends to be negligible unless they are associated with harmful elements or compounds (heavy metals, pollutants, etc.).

2. Biological Quality

The biological quality of water is associated with the chemical quality of water, where the occurrence of organisms depends on the chemical properties of the water (nutrients, toxins, etc.). While direct impacts on the soil or crop tend to be negligible, this water may pose a human health risk due to the introduction of pathogens if sewage and animal waste find its way into a dam or river.

In some rivers and dams bacteria and algal populations are known to explode (bloom) annually in spring when the conditions are favourable for eutrophication to occur (excess nitrogen and phosphorus in the water). These organisms can increase the biological oxygen demand of the water and lead to anaerobic conditions and stagnation and may require filtration to prevent blockages in irrigation systems.

3. Chemical Quality

Chemical properties are the most commonly considered aspect of water quality management for soil and crop performance. The amount and type of chemical substances dissolved in water will influence the quality of irrigation water. Run-off, chemical spills, non-point source pollution and the frequency and intensity of rainfall events all contribute varying levels of salts and toxins to water sources.

Water pH is important as excessively acidic water can corrode irrigation systems, increase the amounts of soluble toxic elements in solution (and consequently the soil) and lead to soil acidification. Alkaline water can increase the bicarbonate or alkalinity hazard (and thus sodicity risk) and precipitate compounds and nutrients in the irrigation pipes and nozzles (leading to blockages).

The most common concern with irrigation water quality is salinity and sodicity impacts and their negative consequences on crop production. Water quality classes in relation to this are described in the following section **(Water classes and suitability for irrigation).**

In some instances toxic ions may also be present either as normal plant nutrients that are present in excessive amounts (e.g. boron, copper, sulphate) or that are inherently toxic (e.g. arsenic, chromium). These problems are infrequent and thus not routinely tested for. However, if a grower suspects or is aware of a water contamination event that may introduce these elements or compounds then it is advisable to have samples evaluated by a laboratory capable of such tests.

Other concerns relate to the occurrence of residual pesticides, herbicides and related compounds. The presence of these residues can lead to poor crop growth and inhibit soil biological health leading to poor crop performance. Specialised laboratory services are required to detect these compounds.

Where water is mixed with fertilisers (fertigation) or other agrochemicals (chemigation), then it is important to ensure that the water quality meets the product label requirements to prevent unintended precipitation or reduced efficacy of the chemicals.

Table 1: Key water quality properties reported by FAS.

Water quality property	Units	Description
pH	None	This is an indicator of the acidity or alkalinity of the water. Ideally good irrigation water will have a pH of 6.5 to 7. Water with a pH < 5 (acidic) can promote soil acidification. Alkaline water (pH > 8) is linked to saline and/or sodic conditions.
Soluble base cations (Ca, Mg and Na)	meq/L*	The concentration of Ca, Mg and Na in the water is used to determine the sodium adsorption ratio (SAR).
Alkalinity (HCO_3)	meq/L*	A measure of the excessive alkalinity present in water as bicarbonate often associated with high pH. It is used to adjust the SAR value for the impact of the excess bicarbonate in solution. It is sometimes also called the residual alkali or bicarbonate risk.
Electrical conductivity (EC)	mS/m	An indicator of the amount of total dissolved salt in water, recorded in milli-siemens per metre (mS/m). Continuous use of water with a high EC can lead to the accumulation of salts in the soil and result in a saline soil.
Sodium Adsorption Ratio (SAR)	None	This represents the ratio of the concentration of Na relative to that of Ca and Mg combined and provides an indication of the potential sodicity impact the water may have. Water with a high SAR can lead to the development of a sodic soil.
Effective Electrical Conductivity (EEC)	mS/m	The crop will receive water from rain and irrigation. EC is measured on the irrigated water and the dilution effect of rain water is taken into account to determine the Effective Electrical Conductivity (EEC). This assumes rainfall is relatively free of dissolved salts. It is therefore important to supply annual rainfall with the water sample. If this is absent then the mean regional rainfall value will be used to determine EEC resulting in a less optimal value. Values <50 mS/m are considered good quality, 50 to 120 mS/m moderate to poor quality and > 150 mS/m, very poor quality. If you are unsure of your annual rainfall consult the SASRI WeatherWeb to obtain this information (www.sasri.org.za).
Adjusted Sodium Adsorption Ratio (ASAR)	None	In alkaline waters, it is likely that carbonates and bicarbonates are present that can precipitate Ca and Mg out of solution and effectively increasing the ratio of Na to Ca + Mg (i.e. increases SAR). To account for the bicarbonate effect, an Adjusted SAR (ASAR) is determined in alkaline samples to determine the water quality class. Values >10 are considered very poor quality, between 5 and 10 is considered moderate to poor and <5 is good quality water.

* meq/L refers to milli-equivalents per litre. The equivalent SI unit is milli-mol charge per litre (mmolc/L).

Table 2: Additional water quality properties.

Water quality property	Units	Description
Total dissolved solids (TDS)	mg/L	Estimates the amount of salt that would precipitate from dissolved salts in the water. It can be roughly estimated (in mg/L) by multiplying EC (in mS/m) by 6.4 for water with EC < 500 mS/m or multiplying by 8 for water with EC >500 mS/m. It is an alternative measure to EC and indicates potential salt loading.
Soluble nutrient and trace ions		Concentrations of plant nutrients such in cationic forms (ammonium, potassium, manganese, zinc, iron, copper) or anions (nitrates, phosphates, sulphates). In most cases these are not normally considered to be problematic, but if present in excessively high concentrations these can lead to leaf and root scorch, toxicities or nutrient imbalances.
Toxic ions and elements		Includes trace or heavy metals and metalloids including aluminium, chlorides, cobalt, lead, nickel, chromium, arsenic, mercury, boron, selenium and fluorides. These are often only analysed where excess amounts are suspected due to pollution. Even low amounts can lead to negative impacts on crop performance.
Dissolved organics		Usually associated with pollutants or contamination, but may include pesticide and herbicide compounds or decomposition products. These are often only analysed where excess amounts are suspected due to pollution or chemical spills.
Pathogens		Usually assessed where there may be contamination from sewage or similar sources. These should be assessed if there is a risk of staff being exposed to the water or if the same water is used for food crops and livestock drinking water.

Water classes and suitability for irrigation

Water quality is classed on its potential to lead to saline and sodic conditions in the soil. The relationship between electrical conductivity (EC) (or their rainfall adjusted equivalent, Effective EC (EEC)) and sodium adsorption ratio (SAR) (or alkalinity adjusted SAR (ASAR)) are the primary determinants of these classes (Figure 1). These classes are provided in the routine water quality analysis report from FAS.

Important considerations when interpreting the water class

When a water sample is classified it is assigned to one of the water quality classes based on the discrete categories shown in Figure 1. However, this can lead to confusion as to the suitability of the water for irrigation under different conditions, especially where samples lie near category class borders. To better guide the suitability and risk associated with using the water it is useful to evaluate where sample lies relative to the colour gradients shown in Figure 1. Samples in the darker green regions indicate low risk except in very dispersive clay soils (typically black clay soils that show cracking when dry), samples in the light green to yellow indicate increasing risk to all dispersive and poorly drained soils (and drainage is advised), while the orange to red transition indicates very high risk to soil quality and the water should not be used for irrigation purposes without treatment.

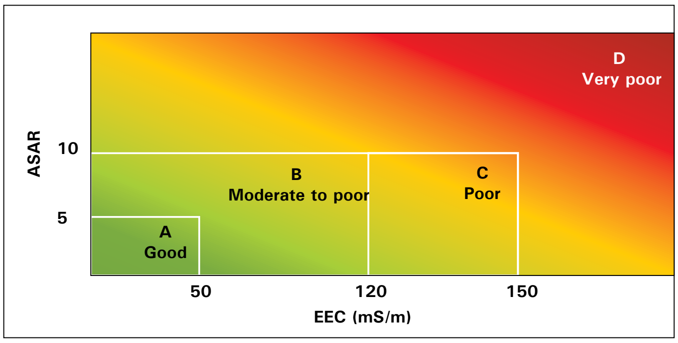

Figure 1: The relationship between the Adjusted Sodium Adsorption Ratio (ASAR) and Effective Electrical Conductivity (EEC) on suitability of water for irrigation. The category borders define the assigned water quality class for reporting purposes, while the green-yellow-red transition highlight the increasing risk gradient across these categories.

Class A

Suitable for use on all irrigated soils. Shrink-swell soil types may still show reduced infiltration and drainage, particularly if they already have excess Na present (reflected in high saturated paste SAR values or exchangeable sodium percentage (ESP) values from soil testing). Ensure drainage is adequate to prevent salt accumulation over time, particularly at high irrigation rates.

Class B

Suitable for irrigation on well-drained soils only (deep red and brown soils, sandy profiles e.g. Hutton, Griffin, Inanda, Magwa, Fernwood). Salinity and/or sodicity hazards make it unsuitable for irrigation of poorly drained soils, e.g. Bonheim, Estcourt, Katspruit, Kroonstad, Rensburg, Swartland and Valsrivier form soils. Where it is used, ensure drainage is adequate to prevent salt accumulation over time.

Class C

Poor quality water which can only be used on very well drained soils (well-oxidised red soils and sandy profiles) if water of better quality is not available. Excessive salinity may reduce the normal crop growth response expected under irrigation. Particular care must be taken to avoid waterlogging, so manage application amounts and ensure good drainage.

Class D

Unsuitable for irrigation of sugarcane under normal irrigation practice. May need to consider water treatment to remove excess salt.

For guidance on typical infiltration and drainage characteristics and susceptibility to salinity/sodicity risk of the common South African sugarcane growing soils consult the **"Identification and management of the soils of the South African sugar industry"** handbook (available at www.sasri.org.za).

Guidelines for water sampling

For a water quality analysis to be representative, the following rules apply when collecting the water sample:

- Use clean, uncontaminated, sealable and non-breakable (ideally plastic) bottles that can hold at least 250ml of water.
- Rinse the container at least twice with the water from the source to be analysed.
- To best represent the water quality that will be applied to the crop, it is advisable to collect the sample from the pump station outlet to represent the water being pumped through the irrigation system.
- Allow the pump to run for several minutes before sample collection to improve sample representativeness.
- Where water samples are to be collected from dams/ponds/rivers/canals then it is important to adhere to the following guidelines:
  - Avoid sampling close to the edge of an open water body e.g. a river or dam.
  - Collect water as close as possible to the intake (abstraction point) of irrigation water.
  - Collect the sample from at least 0.3 m (30 cm) below the water surface.
  - It is usually best to collect several samples and mix these to produce a single composite sample.
  - Fill the container to the top (to minimise headspace) and seal the container immediately.
  - Attach all relevant information required for the testing laboratory including the annual rainfall and irrigation amounts and label samples clearly with markings that will not readily degrade or be rubbed off.

The time period between water sample collection and chemical analysis should be kept to an absolute minimum as chemical and microbial processes can alter the measured results. After collection, the sample should be kept in a cool, dark place (such as a cooler box) until it can be submitted for analysis. If the sample cannot be submitted for analysis within a day of collecting, then it should be refrigerated. Water samples that are not analysed within 5 days (with refrigeration) should be discarded and new samples collected.

Frequency of water sampling

Prescribing the frequency of water sampling is difficult and depends on many factors. If the water body being used for irrigation is known to be stable, less frequent sampling is required, but where there are seasonal volume and quality changes or potential contamination inputs, it is suggested that more periodic sampling be undertaken (at least 2 to 4 times a year to represent major seasonal changes) or when such changes are observed by the grower.

Should you have any further queries or concerns please do not hesitate to contact your regional Extension Specialist or SASRI Research Specialists for assistance.

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