Bio*Ag* Digest-it® for Dairies and its Effectiveness in Promoting Physical and Chemical Changes in Dairy Effluent Ponds

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Overview

Bio*Ag* Digest-it® for Dairies (Digest-it) is a new product in the Bio*Ag* Pty Ltd range of naturally fermented biologically active aids to agriculture. It assists in the digestion of dairy effluent sludge by promoting aerobic bacterial metabolism.

Between November 2008 and December 2009, we conducted a trial designed to show proof of concept of the product and, by analysis, attempt to quantify the advantages to Digest-it users, primarily in terms of increased pond capacity and nutrient recovery.

Trial Design

Four dairy properties in Victoria and New South Wales were selected to be part of the trial. The selection of trial partners was by way of introductions from Bio*Ag*'s distribution partner - Semex Pty Ltd, and differing herd sizes and effluent handling systems were sought. All four ponds were tested on a three weekly cycle for a range of physical parameters.[2] As well, one pond is being tested for changes in a chemical profile.[3]

Visual and olfactory observations were taken on each visit. In addition, still and video images were recorded. Throughout the trial, samples were collected from the same place at each trial pond. A steel peg was used to physically mark the sample point at each pond.

The physical testing was carried out by the laboratories of Rockdale Beef Pty Ltd and the chemical testing by The National Measurement Institute.

Sample Site Overview

Merrigum [Vic.]

This 110-cow dairy has a small effluent pond that was a real problem to the owner. It needed regular mechanical de-sludging and capacity was limited by the heavy crust and build up of solids on the bottom. The crust was thick and heavy enough to partially support the weight of a cow.

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[2] See Appendix A
[3] See Appendix A

Katunga [Vic.]
The 100 x 30 metre pond should have been adequate for this 610-cow dairy, but the owner was having problems with odour, crusting and the pond overflowing into a nearby community drain. Mechanical cleaning was costing the owner over $6000 per episode.

Finley [NSW]
Originally built for a 300-cow dairy, this pond is now servicing approximately 700 cows, Build up of material on the bottom of the pond had blocked the drain to the irrigation system and crust build up had made the overflow difficult to manage.

Blighty [NSW]
This 50 x 25 metre pond is taking the effluent from a 500-cow dairy. It has a relatively short fluid retention time. At the start of the trial it was heavily crusted and in poor condition. Since it seemed to be the pond in the poorest condition, this pond was chosen to for the chemical profile testing.

Product Description
Digest-it is a fermented liquid product containing dormant populations of naturally occurring organisms and is also a rich source of nutrients and other essential microbial elements. After application, the microbial populations break dormancy and increase the numbers of aerobic bacteria present in the pond. It also promotes the growth of the existing microbial populations.

Application
Each pond was 'charged' by applying 10 to 40 litres of diluted Digest-it to the surface using a high-pressure pump. After this, two to four litres of neat product was poured on to the wash down pad once a day before cleaning. This is then washed into the pond along with the effluent from that milking and the wash down water. Application rates were calculated for each pond, based on size, cow numbers and condition. The initial application and some subsequent daily applications had occurred before the trial commenced and sampling began.

Results
Pond Capacity
It is clear from visual observations, and feedback from our trial partners, that the use of Digest-it has increased pond capacity. This is clearly demonstrated in Illustration 1. The Merrigum pond had a crust approximately 500 mm thick, which has been totally dissolved. The depth of the pond was measured at the beginning and end of the trial with an increase of 670 mm over this period. These changes equate to an increase in pond capacity of over 200,000 litres.

In March 2009 the pond at Katunga was removed from the trial, as the owner was able to move from a one-pond system to a two-pond set-up. The partially dissolved crust and increased fluid volume had meant that there was enough liquid to charge the waiting second pond. Associated with the increase in volume was generally cleaner water, which is now being used for washing down the pad. The decrease in total water volume in the first pond also meant that the remaining crust broke down at a greater rate than previously.

Due to operational changes at the dairies and pond usage, it was not possible to document the actual capacity changes at the Finley or Blighty sites

Illustration 1: Merrigum Pond

26 November 2008 – looking west

15 September 2009 – looking east

pH

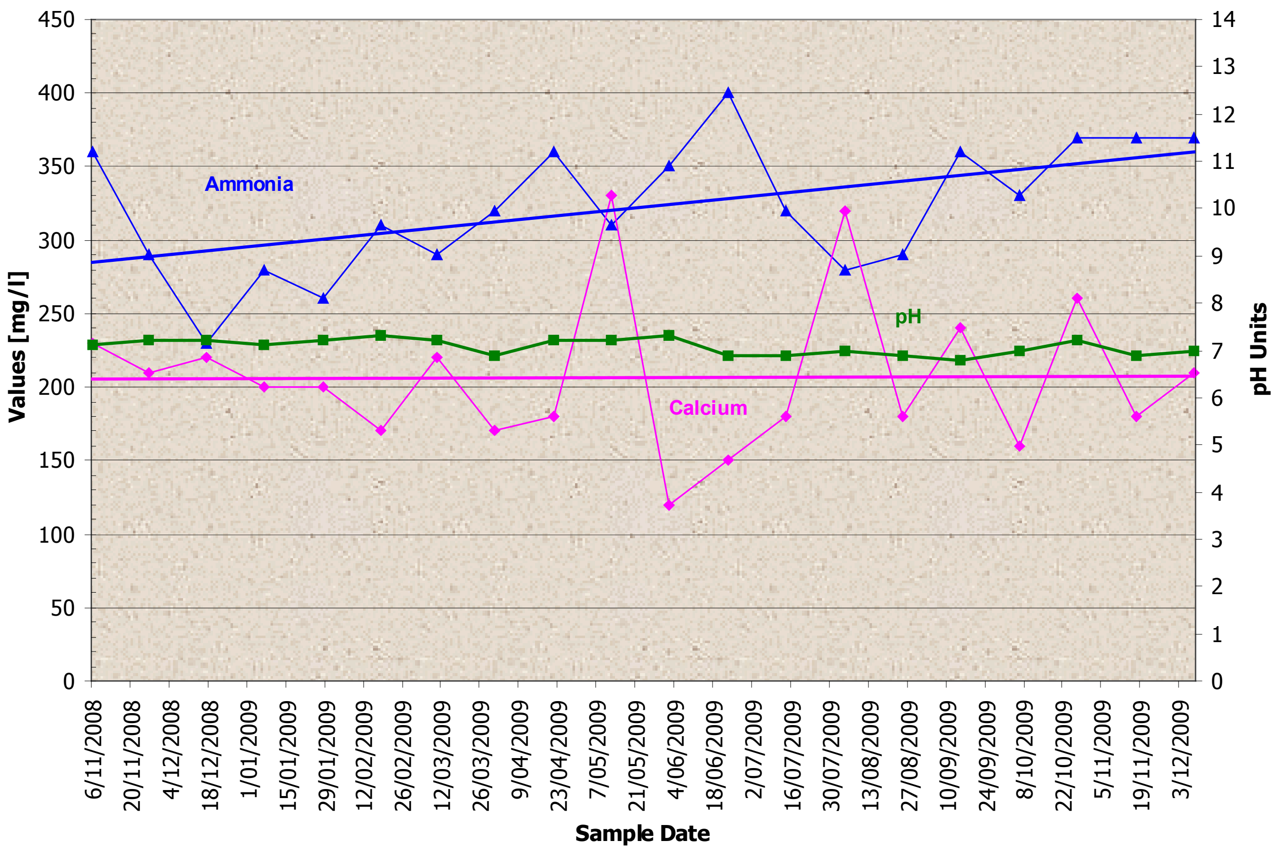
Most untreated effluent ponds are slightly alkaline. Examples are 7.9 for Queensland[4] and 7.3 for the Gippsland in Victoria.[5] The average pH of the four treated ponds in the Digest-it trial is 7.1. See secondary axis of graph 1 (green line) for the results from the Blighty pond.

[4] Effluent and Manure Management Database for the Australian Dairy Industry (2008)
[5] Dairy Effluent – Application to Pastures. Victorian DPI [AG0419]

Total, Dissolved and Suspended Solids

The results from these tests have been variable, resulting from activity within the pond at the time of sampling, changing water levels and sampling variability. Feedback from our trial partners, especially at Katunga, indicates that the water is becoming clearer and visually cleaner.

Graph 1. Other Parameters [Blighty]



BOD5[6]

This generally recognized indicator of water health has shown a downward trend in two of the four ponds. Published data[7] for northeast Victoria indicates that the BOD_5 value of untreated ponds is in the range of 2,500-3,000 mg/l. BioAg in association with Thomson & Joseph Ltd has just commenced trials at a number of dairy sites in the UK; the average untreated BOD_5 of these sites is 7,036 mg/l (n=10).

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[6] See Appendix B

[7] Effluent and Manure Management Database for the Australian Dairy Industry (2008)

Table 1. shows the BOD_5 values of the trial ponds averaged over quarterly periods.

Table 1. Digest-it Treated Ponds BOD_5 Test Results					
Location	2008 Quarter 4	2009 Quarter 1	2009 Quarter 2	2009 Quarter 3	2009 Quarter 4
Merrigum	272	178	298	419	332
Katunga	412	409	NS[8]	NS	NS
Finley	934	404	357	995	274
Blighty	521	308	366	411	202

An almost complete emptying of the Merrigum and Finley ponds just prior to a sampling run skewed the results for these two trial sites during the 3rd quarter of 2009.

It is clear that the use of Digest-it has improved water quality as measured by BOD_5. The levels at all sites are well below published data and our UK results. The Finley and Blighty sites are trending downwards. The results for the Merrigum site are influenced by regular pumps outs.

<u>NPK Indices</u>
There is a good deal of variation in the individual results for the Kjeldahl Nitrogen, Total Phosphorus and Total Potassium. This could be due to the activity of the pond and time of sampling, the weather conditions and sampling variation.

Table 3. shows the Queensland average, the average of three Victorian regions and the average of untreated BioAg client ponds throughout southern Australia (n=10) compared with NPK analyses for the Blighty site. The results are expressed in mg/l. This unit is equivalent to kg/ML of fertilizer if the treated water was used for irrigation. The data show that nutrient levels in the treated pond are such that for a typical irrigation application rate the pond water now needs to be diluted to avoid nutrient overload, based on Victorian DPI recommended nitrogen application rates. By analysis we have found that over 95% of the total phosphate is in a bioavailable form.

Table 3. NPK Nutrient Levels (mg/l)				
Parameter	Qld[9]	Vic[10]	Bio*Ag* Untreated Mean	Bio*Ag* Blighty Mean
Nitrogen	167	283	248	538
Phosphate	36	76	40	141
Potassium	274	409	350	774[11]

[8] No sample
[9] Effluent and Manure Management Database for the Australian Dairy Industry (2008)
[10] Dairy Effluent – Application to Pastures. Victorian DPI [AG0419]
[11] All water used in the dairy id from a bore, this may be a contributing factor to the potassium level.

An unpaired student t-test ($p<0.05$) has been conducted for each of the NPK analysis comparing the Blighty results with BioAg client's untreated ponds (n=14). The results were that the differences between the two data sets are to be considered 'extremely statistically significant'. In other words the use of Digest-it has resulted in changes to the NPK levels.

<u>Other Nutrients</u>
Table 4. shows the levels of other nutrients in the treated pond at Blighty and the average result for 10 untreated ponds tested by Bio*Ag* on behalf of clients in southern Australia, including Tasmania. The ammonia results are from four ponds only.

Graph 1 shows the calcium levels (pink line) and the ammonia levels (blue line) over the trial period. Although the results varied, the overall level of calcium did not alter significantly. The ammonia levels trended upwards over the trial period, indicating increasing effectiveness of the pond as an effluent treatment system. It is likely that some of this ammonia will be lost through volatilisation.

Table 4. Nutrient Levels (mg/l)		
Parameter	Untreated Ponds	Blighty [NSW]
Calcium	141	207
Magnesium	75	214
Chloride	548	1,305[12]
Ammonia[13]	210	323

<u>Odour</u>
At this stage, odour is essentially, an amenity issue. However with increased urbanisation and increasing population on the urban/rural interface, there will be an increased emphasis on odour control either by way of community pressure or regulation. This is already evident in the licence conditions placed on large-scale cattle feedlots. There is no doubt that one of the first things that is noticed by all users of Digest-it is a reduction in the offensive odour normally associated with untreated effluent ponds.

Discussion

In this trial we were dealing with a dynamic biological system. The owners of the trial sites continued to utilize the ponds at all times. Fluid was drained, effluent added, rain has come and gone, and our trial partners have been in charge of dosing the pond - not always exactly according to our recommendations. There was considerable biological 'bounce', so rather than rely on each data point, it is more meaningful to look at the trend patterns appearing.

[12] All water used in the dairy is from a bore, this may be a contributing factor to the chloride level.
[13] Four ponds only, not the 10 ponds of the other nutrients

Effective pond capacity has undoubtedly increased. See Illustration 1. as an example. All ponds in the trial display similar increases in effective capacity. The Blighty site is the slowest mover in this regard.

The Blighty site, where we have been taking our nutrient samples, was especially difficult to manage. The farmer involved now considers that the pond is overloaded. There is very little retention time, with continuous flow at the discharge point to compensate for inflows. At the beginning of the trial period there was a relatively thick crust, over a liquid layer and a compacted sludge bottom. Over the trial period, the thickness of the surface crust has decreased and there has been some digestion of the bottom sludge. The outcome of this process is that the liquid layer has been replaced by a slurry phase. The inflows then seem to channel through the slurry rather than spread out across the pond area. At times it has been difficult to get a liquid sample from this slurry phase.

Illustration 2: Blighty - Channelling
05 January 2010

There is no doubt that the BOD_5 of our trial ponds is lower than industry datum points and the trend is that the BOD_5 is continuing to drop over time. One would expect that this trend will plateau at some stage.

Results of the trial show that nitrogen and phosphate values have increased as a result of digestion of the crust and sludge from the bottom of the ponds.

In associated testing at the Finley site the nitrogen level of the sludge was just under 2%; this forms a considerable nutrient 'bank' that should become available as Digest-it does its work.

Potassium levels although initially higher than industry data are decreasing. Some of the higher than expected levels may result from the use of bore water by the Blighty dairy; at this time I do not have a water analysis for this site. However the potassium trend appears to be sloping downwards. This is mostly likely due to dilution as the effective pond capacity increases.

In untreated ponds, most of the potassium is in solution and most of the nitrogen and phosphate is locked in the crust and the sludge. As Digest-it continues to stimulate the digestion process, more of the nitrogen and phosphate will be released into the liquid phase, and the potassium levels will decrease due to dilution; then all three essential nutrients may come into balance.

While odour is essentially an amenity issue, the reduction in the release of hydrogen sulphide (rotten egg gas) indicates that more sulphur is being trapped in the system. It may well be that nitrous oxide compounds (NOXs) are also being captured. With increasing urban creep and mixed farming communities, it is certain that odour will become a more important issue over time.

Conclusion

While not fulfilling all of its aims, this trial clearly shows that the use of Digest-it has an effect on a number of chemical and physical properties of dairy effluent ponds.

- The fluid holding capacity of the ponds has increased.
- The nitrogen and phosphate levels of the liquid phase have increased due to the digestion of the surface crust and the sludge that had settled on the bottom of the pond.
- The soluble potassium level in the fluid phase has decreased due to the increase in retention volumes.
- The ph value has been neutralised.
- The BOD_5 levels have decreased from industry published figures, indicating an improvement in water quality.
- Odour levels have decreased.

11.01.10

APPENDIX A

Analytical Testing – Digest-it® for Dairies Project [Bio*Ag* Pty Ltd]

Aim

In setting up the analytical testing regime we were looking for a key or keys that would give a clear indication that Digest-it® for Dairies is working in the trial ponds. Before this we were relying on visual and olfactory indicators. Because the nature of the key(s) was unknown, we aimed at a broad spectrum of testing.

Scope of this Paper

In this paper I have attempted to explain each component of the current testing regime. Also, there is some indication as to whether or not the indices are adding value to our analysis profile and, for some, the direction we would like to see them moving.

Physical Test Profile

A definition section is included at the end of this paper which may help with understanding some of the testing parameters.

Total Plate Count (TPC)

TPC are being measured both for both aerobic [TPC (O_2)] organisms and anaerobic [TPC (AN-O_2)] organisms. Aerobic TPCs are being performed at two different temperatures to capture the majority of aerobic organisms.

Associated with these tests is an Aerobic: Anaerobic Ratio [Total Aerobes divided by Total Anaerobes]. We are looking to turn the ponds from a predominately anaerobic system to an aerobic one.

Biochemical/Biological Oxygen Demand (BOD_5)

This measures the amount of oxygen demanded by the water biology. It is a five day test. Because we are working in a sewage system, these values are obviously much higher than other waters, but as the biology change then the BOD_5 moves around. The trend on all ponds is downwards this is the way any waste authority looking at the results would like to see it going.

Chemical Oxygen Demand (COD)

As the definitions explain, COD is the total oxygen demand of the system. It takes into account both organic and inorganic demand. It is associated with the BOD_5 and isn't really adding value to our observations at this time

Dissolved Oxygen ($DisO_2$)

As the name implies, this is a measure the level of oxygen in the sample. It is necessary parameter in determining the BOD_5 and the COD, but by itself isn't adding value to our observations.

Conductivity

This is a measure of the charged ions in the sample. It is a term understood by most of our potential clients in relationship to irrigation and groundwater water levels. Levels in our ponds aren't changing much indicating (as one might expect) relatively high levels of ions in the ponds.

pH

The ponds are maintaining a pH level from neutral to slightly alkaline.

Turbidity

This is a measure of how murky the sample is. This parameter is varying somewhat, but is most likely reflecting sampling differences and microbial activity in the pond at time of sample. By itself isn't adding value to our observations.

Solids – Total (TS), Suspended (TSS) and Dissolved (TDS)

Again these results are varying, especially TS and TSS readings. The variation could be due to some extent to sampling variations, but mostly they reflect the activity of the pond at time of sampling. On days of high activity (bubbling/"bolling") then the TS and TSS seem to be higher than on quiet days. While ever there is material to be digested I would expect these results to continue to be variable.

Chemical Test Profile

We are conducting the Chemical Test Profile on only one of our four trial ponds. At the time of setting up the trial profile, this was the least advanced of our ponds and hopefully over time will give a good indication of changes to the indices as Digest-it has its effect.

Calcium (Ca), Magnesium (Mg), Potassium (K) and Chlorine (Cl)

These need no explanation and represent the levels of those elements in the respective sample. Increases in calcium, magnesium and potassium would be good, increases on chlorine less so.

Phosphates

We are measuring three phosphate variants: Total Phosphate –a measure of all the phosphate that is available in the system, Bioavailable Phosphate –a measure of phosphate salts, Organic Phosphate (from flora) and other acid soluble sources of phosphate. It excludes mineralized phosphate. Almost all the phosphate in the system seems to be in a bioavailable form. Soluble Orthophosphate Phosphate is essentially phosphate in solution. While we held out hope in the early days that this would prove a useful indicator, as time goes on I'm less convinced as to its usefulness.

A large proportion of the phosphate in the system is tied up in the sludge and over time we would like to see an increase in Total Phosphate and Bioavailable Phosphate.

Sodium Absorption Ratio (SAR)

This ratio measures the ratio of sodium ions to calcium/magnesium ions. A high SAR would indicate waste water unsuitable for use as irrigation water. Based on information from the Qld DPI website (see Definitions) the use of gypsum on paddocks irrigated from our test pond may also be indicated

Nitrogen

Again we are measuring a number of nitrogen parameters. Kjeldahl-N is the total nitrogen and includes the all organic and inorganic N sources. See the definitions at the end of this paper for a more detailed explanation of the nitrogen parameter. Up to 50% of the excreted N may be lost from the system through volatilization. However, another approximately 20% is tied up in the sludge component, and as we digest this sludge we would expect an upwards trend in overall N levels.

APPENDIX B

Definitions

Taken from a number of Internet sources

Chemical Oxygen Demand (COD)

The amount of **oxygen** (measured in mg/L) that is consumed in the oxidation of organic and oxidisable inorganic matter, under test conditions. It is used to measure the total amount of organic and inorganic pollution in wastewater. Contrary to BOD, with COD practically all compounds are fully oxidized.

http://en.mimi.hu/environment/chemical_oxygen_demand.html

Chemical Oxygen Demand (COD): A measure of the oxygen required to oxidize all compounds, both organic and inorganic, in water.

http://www.water-technology.net/glossary/chemical-oxygen-demand.html

Biochemical Oxygen Demand (BOD)

The amount of **oxygen** (measured in mg/L) that is required for the decomposition of organic matter by single-cell organisms, under test conditions. It is used to measure the amount of organic pollution in wastewater.

http://en.mimi.hu/environment/chemical_oxygen_demand.html

Biochemical Oxygen Demand (BOD): A measure of the amount of oxygen consumed in the biological processes that break down organic matter in water. The greater the BOD, the greater the degree of pollution.

http://www.water-technology.net/glossary/chemical-oxygen-demand.html

Turbidity

- Turbidity is a measure of cloudiness in water. The more turbid the water, the murkier it is.
- Turbid waters become warmer as suspended particles absorb heat from sunlight, causing oxygen levels to fall. (Warm water holds less oxygen than cooler water.) Photosynthesis decreases with lesser light, resulting in even lower oxygen levels.

Dissolved Oxygen

- Fish, invertebrates, plants, and aerobic bacteria all require oxygen for respiration.
- Much of the dissolved oxygen in water comes from the atmosphere. After dissolving at the surface, oxygen is distributed by current and turbulence. Algae and rooted aquatic plants also deliver oxygen to water through photosynthesis.
- The main factor contributing to changes in dissolved oxygen levels is the build-up of organic wastes. Decay of organic wastes consumes oxygen and is often concentrated in summer, when aquatic animals require more oxygen to support higher metabolisms.

pH

- A range of pH 6.5 to pH 8.2 is optimal for most organisms.

Biochemical Oxygen Demand

- Biochemical oxygen demand is a measure of the quantity of oxygen used by micro-organisms (e.g., aerobic bacteria) in the oxidation of organic matter.
- Oxygen consumed in the decomposition process robs other aquatic organisms of the oxygen they need to live. Organisms that are more tolerant of lower dissolved oxygen levels may replace a diversity of more sensitive organisms.

Nitrates

- Nitrogen occurs in natural waters as nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), and organically bound nitrogen.
- Excessive nitrates stimulate growth of algae and other plants, which later decay and increase biochemical oxygen demand as they decompose.

Total Phosphate

- Phosphorus is usually present in natural water as phosphates (orthophosphates, polyphosphates, and organically bound phosphates).
- Phosphorus is a plant nutrient needed for growth and a fundamental element in the metabolic reactions of plants and animals (hence its use in fertilizers).

Conductivity

- Conductivity is also a good measure of salinity in water. The measurement detects chloride ions from the salt. Salinity affects the potential dissolved oxygen levels in the water. The greater the salinity, the lower the saturation point.

Ammonia

- Nitrogen occurs in natural waters as nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), and organically bound nitrogen.

http://www.fivecreeks.org/monitor.html

Nitrate (NO3), Nitrite (NO2), and Ammonia (NH4)

- Are considered inorganic forms of nitrogen and are analysed separately in wastewater's to determine the total inorganic nitrogen.

Total Kjeldahl nitrogen (TKN)

- Is the combination of organically bound nitrogen and ammonia in wastewater. The organically bound nitrogen must be released from the organic matter by a process of digestion prior to analysis. This form of nitrogen is usually much higher on influent (untreated waste) samples then effluent samples. In most domestic wastewater facilities the biological activity breaks down the organic matter releasing and or consuming the nitrogen as energy in the process. Total nitrogen is the combination of organic nitrogen and inorganic nitrogen (NH4, NO3, NO2).

http://www.bfhd.wa.gov/info/tkn.php

Solids Analysis

- Solids are categorized into several groups based on particle size and characterization. Most wastewaters are analysed for one or several of the following types.

Total Suspended Solids (TSS)
Total Dissolved Solids (TDS)
Total Solids (TS)

Analysis of solids in domestic wastewaters allow system operators to determine treatment efficiency as well as determining compliance with various regulatory agencies.

Total Suspended Solids

TSS are the amount of filterable solids in a water sample. Samples are filtered through a glass fibre filter. The filters are dried and weighed to determine the amount of total suspended solids in mg/l of sample.

Total Dissolved Solids

TDS are those solids that pass through a filter with a pore size of 2.0 micron. or smaller. They are said to be non-filterable. After filtration the filtrate (liquid) is dried and the remaining residue is weighed and calculated as mg/l of Total Dissolved Solids.

Total Solids

TS are the total of all solids in a water sample. They include the total suspended solids, total dissolved solids, and volatile suspended solids.

http://www.bfhd.wa.gov/info/tss.php

Sodium adsorption ratio (SAR)

The sodium adsorption ratio measures the relative proportion of sodium ions in a water sample to those of calcium and magnesium. The SAR is used to predict the sodium hazard of high carbonate waters especially if they contain no residual alkali.

The sodium adsorption ratio is used to predict the potential for sodium to accumulate in the soil, which would result from continued use of a sodic water, referred to as the **Exchangeable Sodium Percentage (ESP).** A water sample with a high SAR and a low RA usually has high sodium content due to the predominance of sodium chloride.

Table 2. Sodicity classes for irrigation water

Sodium adsorption ratio	Residual alkali	Sodicity class
Less than 3	Less than 1.25	No sodium problem
3 to 6	Less than 1.25	**1.** Low sodium, few problems except with sodium sensitive crops.
6 to 8	Less than 2.5	**2.** Medium sodium, increasing problems; use gypsum and not sodium sensitive crops.
8 to 14	Less than 2.5	**3.** High sodium - not generally recommended.

http://www2.dpi.qld.gov.au/fieldcrops/3472.html