Fertigation

CASE STUDY 2 - AUSTRALIAN GOVERNMENT REEF PROGRAMME

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FERTIGATION

Fertigation is the practice of applying fertiliser in a liquid form to a crop via the irrigation system. Using the irrigation system to apply fertiliser reduces the need to use mechanical operations and sometimes eliminate them altogether. More and more we are seeing greater percentages of annual crop fertiliser requirements being applied via fertigation, to the point where some cropping systems receive 90-100 per cent by this method. When combined with an efficient irrigation system both nutrients and water can be manipulated and managed to obtain the maximum possible yield of marketable production from a given quantity of these inputs.

Fertigation is typically used to address fertiliser deficiency which inhibits plant growth, labour and operational efficiencies. Fertigation has many advantages and disadvantages.

The advantages include:

- fertiliser can be applied directly to the root zone optimising plant growth
- nutrients can be applied any time during the growing season based on crop need
- highly mobile nutrients such as nitrogen can be carefully managed to ensure rapid crop uptake
- fertiliser can be applied quickly to address any deficiency issues
- minimal crop damage
- tractor operations are reduced, saving fuel, wear and labour
- well-designed injection systems are simple to use and suit automation
- smaller amounts of fertiliser are applied which often results in reduced off site impacts
- reduced loss of fertiliser due to unseasonal weather.

Disadvantages of fertigation include:

- heavily reliant on the efficiency of the irrigation systems distribution uniformity
- heavily reliant of overall irrigation infrastructure design / layout depending on injection point
- potential issues during wet weather

Things to consider:

- How and where to mix the fertiliser – will it be done at the shed or in the paddock?
- Is the right handling, mixing and transport equipment in place?
- Are the occupational health and safety (OH&S) requirements in place?
- Good calibration is essential for economical control.
- Install an anti-backflow check valve to prevent injected fertilisers from siphoning into the water source.
- Install an in-line check valve at the point of injection into the main line to prevent flow of water from the irrigation system back into the mixing tank – and avoid overflow of fertiliser.
- All systems should only commence injection after the irrigation system is pressurised.

SYSTEM DESIGN

There are four injection methods which can be used and the one you choose will primarily depend on the type of irrigation system used.

For continuous moving irrigation systems (centre pivot / lateral move), venturi injectors and positive displacement (pressure) pumps are best. For non-mobile systems (drip / micro / overhead spray) these injections systems can also be used, as well as suction injection and pressure differential.

Venturi injection

Venturi injectors come in several sizes and can be operated under different pressure conditions. Venturi injectors are only usable on closed pipe systems as they are set up in a shunt pipeline parallel to the main irrigation pipeline close to the pivot or lateral structure.

Requiring at least a 20 per cent pressure differential to work properly, irrigation water from the main pump is passed through the venturi unit, creating a pressure differential between the water bypassing the unit and the fertiliser solution in the tank. This pressure differential causes the solution to be drawn up into the mainline. The gate valves and flow rate control the rate of the fertiliser solution applied. The venturi draws all the fertiliser until the tank is empty. Venturi injectors do not require external power to operate but some units utilise a small booster pump in the shunt pipeline to produce a differential pressure. Injection rates of 10 to 20,000 litres per hour can be achieved.

The advantages include:

- no moving parts – typically manufactured from plastic
- requires little maintenance
- gate valves control fertiliser injection rates with some accuracy
- large volumes can be mixed and stored on site
- reduces OH&S issues in dealing with fertiliser.

Disadvantages include:

- requires a closed pipe system
- requires pressure loss in main irrigation line (can be up to 33 per cent)
- automation is difficult but not impossible.

Positive displacement

This is the most common method of injection of fertiliser into irrigation systems and is very accurate. The three systems available are electric injection pumps, piston-activated pumps and diaphragm activated pumps. Piston activated and diaphragm activated pumps are both hydraulic injection pumps. Electric injection pumps include single or multiple piston, diaphragm, gear and roller pumps.

Chart 1: Injected concentration over time using a venturi system

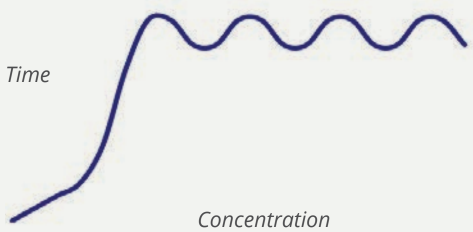
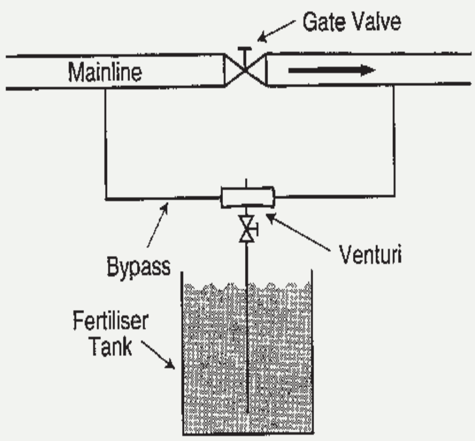


Chart 2: Schematic diagram of a venturi system



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Piston-activated pumps

- Uses a piston or diaphragm to inject fertiliser into the main line from a storage tank.
- Pumps are driven by electricity, petrol or water.
- Irrigation water operates a hydraulic motor that pumps the fertiliser solution into the system. Since the pump's maximum rate of injection is proportional to the pressure in the mainline, the required injection rate is easily adjusted by throttling the injection line by means of a valve fitted to the water main, and as the injection rate per pulse is known, the exact application of nutrients can be readily calculated.
- For high injection rates, two or more units can be operated in parallel. Injection rates of up to 320 litres/hour are possible.

Diaphragm-activated pumps

- Water pumped into the lower chamber activates a rubber diaphragm in the drive unit which forces the diaphragm up, and in doing so forces the fertiliser out of the injector into the irrigation system via a drive rod. On the return stroke the spent drive water is discharged from the lower chamber of the drive unit while simultaneously fertiliser solution is drawn into the injector. The cycle is automatically repeated.
- Injection rates from 3 litres to 1200 litres per hour are possible. There is an upper limit to the pressure available and these pumps might not operate on high head systems.
- Electric injection pumps include single or multiple piston, diaphragm, gear and roller pumps.

These can be regulated to achieve the desired rate by:

- adjusting the length of the stroke of piston pumps
- selecting the appropriate pulley diameter
- using a variable-speed motor
- using semi-automation to adapt the pump to receive electrical impulses from a water meter which can then be used to apply precise amounts of fertiliser

- adjusting the length of the stroke of piston pumps
- metering flow
- manipulating pump speed at the pulley
- using a variable-speed motor
- semi-automation via electronic pulse water meters.

Advantages include:

- simple and effective
- relatively easy to install
- no pressure loss in the main irrigation line
- automation is relatively easy.

Disadvantages include:

- pumps must develop a minimum mainline pressure to operate
- potentially need electric power source to operate
- require a certain level of maintenance
- selected pump must be stainless steel and/or have a bronze impellor
- There are a large number of working components
- The pumps are sensitive to air pockets and need a continuous water discharge to operate the piston or diaphragm
- The spent 'drive water' is lost and discharged from the system.

Suspension Injection

This injection method utilises the irrigation pump suction capacity to draw fertiliser from an open tank, typically of variable size (44 gallon drum to 20,000 l molasses tank).

- Large tanks enable large quantities of fertiliser to become suspended in solution and tobe readily injected. Using a large tank provides a known fertiliser : water ratio.
- Small tanks / drums typically require water to be continuously added during the fertigation event to ensure all the fertiliser in the drum becomes suspended and thus injected.

Disadvantages

- risks of air entering system, pump corrosion, contamination
- pump should be stainless steel and or fitted with a bronze impeller
- flushing the system is even more important.

Advantages

- very simple to operate; a stock solution does not have to be premixed
- easy to install and requires little maintenance.

Chart 3: Injected concentration over time using a Positive Displacement (Direct Injection) system

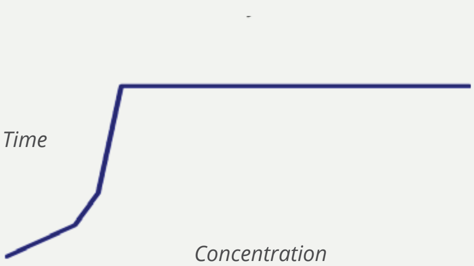


Chart 6: Injected concentration over time using a Suction Injection system with a drum

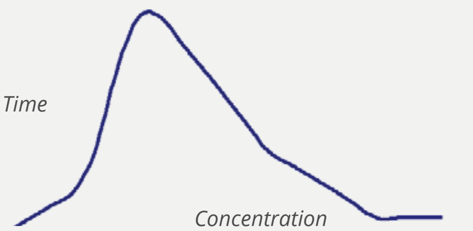
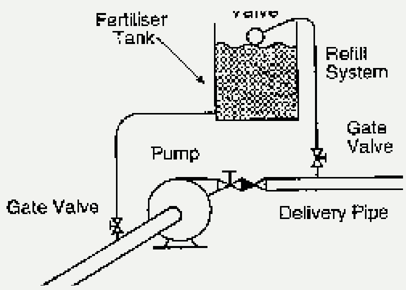


Chart 7: Schematic diagram of a suction injection system



Pressure differential

Pressure differential tanks are closed tank systems that require a minimum of 35 kPa pressure difference from inlet to outlet to operate correctly. Normally used at the field near filter banks, these tanks are prefilled with the required quantity of fertiliser for the block in question, filled with water, closed and then pressurised via the mainline. As a general rule 6-8 tank volumes of water are required to pass through the tank to ensure all fertiliser has been injected.

Disadvantages of PD and Suction systems

- inject rate is important due to the decreasing concentration of solution over the course of the fertigation period
- limited capacity
- danger of suction air entering the system unless all fittings are airtight
- risk of contamination of water supply if chemicals flow back down the suction pipe when the pumping unit stops. A check valve is necessary

Chart 8: Injected concentration over time using a Pressure Differential (PD) tank

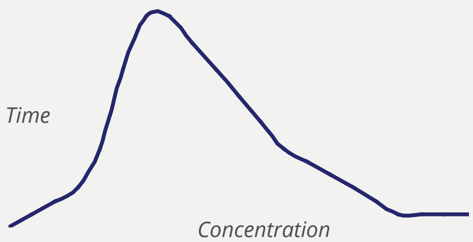
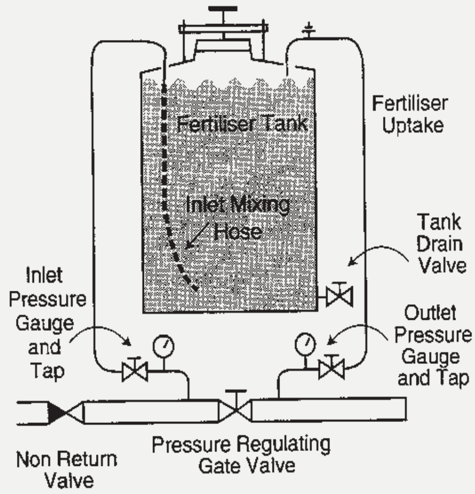


Chart 9: Schematic diagram of a Pressure Differential (PD) tank



SOLUBILITY

Not all fertilisers are suitable for fertigation as some are insoluble due to their chemical properties or manufacture.

As a rule of thumb the following chemical properties should be adhered to in determining the solubility of certain fertilisers:

A. All ammonium, nitrate, potassium, sodium and chloride salts are soluble.

B. All oxides, hydroxides and carbonates are insoluble.

C. All sulfates are soluble, except for calcium sulfate.

Using these rules, calcium nitrate is soluble (rule A), calcium carbonate and magnesium carbonate (lime & dolomite) are insoluble (rule B), magnesium sulfate (Epsom salts) is soluble but calcium sulfate (gypsum) is not soluble (rule C).

Consideration also needs to be given to these rules of thumb when different fertilizers are mixed in solution and applied together as it is possible that a precipitate (sediment) may form. For example, if calcium nitrate and potassium sulfate are mixed together they separate and reform as potassium, nitrate and calcium sulfate (gypsum).

It is generally safe to mix: urea, muriate of potash, potassium nitrate and chelated trace elements.

Phosphates, sulphates, calcium, magnesium and trace elements are problematic as insoluble reaction products may form in the mixing tank.

Due to the manufacture of certain fertiliser products and their purpose of use some contain insoluble impurities, coating agents or granulation:

- These impurities may block filters, emitters and potentially large sections of irrigation infrastructure (drip tape blocks)
- Some fertilisers that may be used in fertigation programs are coated. The coating agents are used to improve the handling characteristics as a dry solid before the products are used. When these products are dissolved in water the coatings begin to break down and may present problems with blockages of filters and small emitters.
- Some fertilisers have a coarse particle size and take a long time to dissolve. Coarse, granular and prilled products can be used, provided they do not contain excessive amounts of impurities. However they may require more agitation. To resolve this, source soluble fine or solution grade products that dissolve more quickly.

The maximum solubility of a fertiliser in water, while temperature dependent, is a physical constant. As a fertiliser solution becomes more concentrated it becomes increasingly difficult to dissolve more fertiliser. When no more fertiliser can be dissolved regardless of continual agitation, the solution is at saturation point. Any remaining undissolved fertiliser has the potential to precipitate. Some fertilisers also cause the temperature of the solution to fall which reduces the solubility e.g. urea and nitrates.

Fertilisers have different solubilities therefore need different amounts of water to dissolve and should be completely mixed before being injected. This is where agitation plays an important role in the effectiveness of injection. Agitation is easier in vertical tanks as there is a smaller surface area at the base of tank. It is also essential that the mix is testedfor corrosion potential and deposition - phosphorous has high a corrosion potential when used in galvanised iron.

Good agitation and a fine particle size results in a quicker dissolve rate, but the maximum concentration that is able to be dissolved does not change.

Table 1: Solubility rating of various fertiliser products

Product	kg / 100 L @ 20° C	Product	kg / 100 L @ 20° C
Ammonium nitrate	192	Calcium nitrate	60
Ammonium sulphate	75	Magnesium sulphate	71
Mono-ammonium phosphate MAP	37	Magnesium nitrate	71
Liquifert P (Tech MAP)	20	Soluble boron	9.5
Mono-potassium phosphate MKP	12	Zinc sulphate	44
Potassium chloride	34	Liquifert K (KCl)	20
Potassium nitrate	8	Liquifert N (Urea)	25
Potassium sulphate	10	Urea (water temperature 5° C)	45

If you are considering applying two chemicals at once, test the compatibility with each other and with the irrigation water as a precipitate (sediment) may form. Manufacturers can help out here and are able to advise on the corrosion potential of their products.

Urea, muriate of potash, potassium nitrate & chelated trace elements are generally considered safe to mix. However phosphates, sulphates, calcium, magnesium and trace elements can create problems. When this happens the following can occur:

- Precipitates may settle to the bottom of the tank or block filters and emitters.
- Precipitates may also form if the water is hard (i.e. high in calcium and magnesium or contains carbonate).

Therefore the trace elements to avoid are copper, zinc, manganese and iron sulphates. These cannot be mixed with calcium nitrate, MAP or MKP. Always use chelated forms of trace elements if mixing products.

Table 2: Product compatibility chart

COMPATIBILITY CHART	Urea	Ammonium nitrate	Ammonium sulphate	Mono-ammonium phosphate MAP	Mono-potassium phosphate MKP	Potassium nitrate	Potassium sulphate	Potassium chloride	Calcium nitrate	Magnesium sulphate	Soluble boron
Urea			✓	✓	✓	✓	✓	✓	✓	✓	✓
Ammonium nitrate	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Ammonium sulphate	✓	✓		✓	✓	✓	✓	✓	NO	✓	✓
Mono-ammonium phosphate MAP	✓	✓	✓		✓	✓	✓	✓	NO	NO	✓
Mono-potassium phosphate MKP	✓	✓	✓	✓		✓	✓	✓	NO	NO	✓
Potassium nitrate	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Potassium sulphate	✓	✓	✓	✓	✓	✓		✓	NO	✓	✓
Potassium chloride	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Calcium nitrate	✓	✓	NO	NO	NO	✓	NO	✓		NO	NO
Magnesium sulphate	✓	✓	✓	NO	NO	✓	✓	✓	NO		NO
Soluble boron	✓	✓	✓	✓	✓	✓	✓	✓	NO	NO	

The options for **applying Incompatible products** include:

- Apply the fertilisers at different times (e.g. apply MAP or MKP and sulphate fertilisers at different times to calcium fertilisers).
- Alternate between the products during the crop (e.g. use two mixing tanks and injectors - the concentration of nutrients in the irrigation lines is very dilute and therefore there is less chance of precipitate formation.)

SYSTEM PERFORMANCE

The performance of fertigation systems depends on the injection type used and the application system. Correct injection rates and an application system that applies water uniformly are crucial to ensure that the distribution of fertiliser is uniform and effective.

To ensure fertiliser is delivered to the field as required, it is necessary to understand the hydraulics of your application system. Depending on the size of the irrigated property the application system may be in several components. It is therefore beneficial to understand all delivery points. Essentially each irrigated field has an individual hydraulic characteristic.

- Check travel time of the irrigation system and recalculate the fertiliser injection rate for the planned amount of fertiliser.
- Prevent back-flow from the irrigation lines into the water supply. This is more likely to occur where suction systems, on the inlet side of the pump, are used to introduce fertiliser solutions.
- Avoid injection into empty lines.
- With travelling irrigation systems, the fertiliser solution must be injected continuously at a constant rate (and concentration).
- After the fertigation process has started, recheck the fertiliser injection rate.
- Periodically revisit the irrigation system and recheck the operation of the injection meter, operating pressure of the system and water distribution of the irrigation system including the end gun operation on centre pivots.
- At the end of each fertigation application continue running water through the irrigation system until all of the fertiliser has been discharged from the pipeline of the irrigation system. The time will vary depending on the distance between the fertigation tank and the irrigation system. Also run clean water through the injection meter, chemical discharge hose and check valve. Flushing after use prevents scale forming and extends the life of gaskets and metals.
- Maintain a neat storage, mixing and injection area. This promotes safe handling and facilitates early recognition and clean up of any spills and leaks.
- Prevent drainage from the injection / storage area into streams, dams or bores.

Before any test is started, the system must be operating at its normal operational pressure. Once the system is running at the correct pressure, commence injecting.

Injection times and flushing procedure will vary between different irrigation blocks. Select the desired system to check and then start the injection process, being sure to make a note of the injection time (See diagram over page - A).

Calculate the time it takes for the fertiliser to reach the first emitter/sprinkler (A – B). If fertiliser injection is done at the actual block or irrigation system this time will be minimal but if the fertiliser is injected at the pump some distance away it can take quite a while to get there depending on the sizes of mains / sub-mains.

Now measure the time it takes to get from the first emitter/sprinkler to the last emitter/sprinkler of the centre pivot / lateral move (A - C). Take a note of this time as this is relevant to the injection time at the fertiliser tank.

For drip and micro systems there are a range of methods that can be used to measure timing. Nitrate test strips can be used with a nitrate fertiliser. This is simple as you do not need much nitrate fertiliser in the tank for it to be effective. EC meters (salts), pool test kits (acid and chlorine), molasses and dyes can also be used to check the system.

For large irrigation systems such as centre pivots, lateral moves and possibly overhead systems, the ability to track fertiliser movement may be difficult given high flow rates. An alternative to direct measurement is to complete a velocity of flow calculation using the following calculation:

Velocity (m/sec) = 1.274q / d2

where

q = Volume flow (m3/sec)

d = pipe inside diameter (m)

Example:

8" pipe and a flow rate of 100 L/sec

8" = 200 mm = 0.2m

100 L/sec = 0.1 m3/sec

Thus:

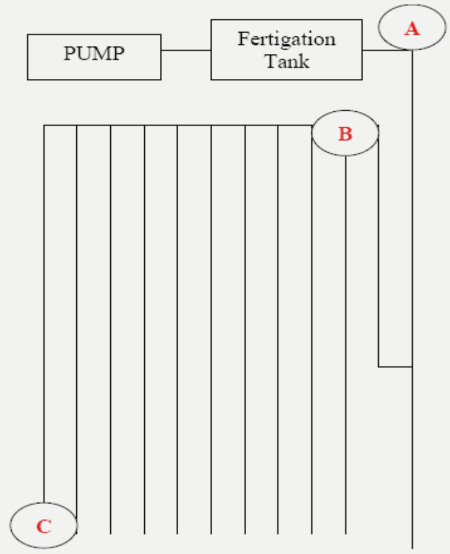
V = (1.274 x .1) / 0.22

V = (0.1274) / 0.04

V = 3.185 m/sec.

This velocity can be used to estimate the time taken for fertiliser from the injection point to leave the system. If the distance from the injection point to the end of the overhead system is 1000 m then the time taken will be 314 seconds or five minutes and 14 seconds (1000m/3.185 m/sec).

Chart 10: Schematic diagram of drip / micro irrigation system



A = Fertigation Tank

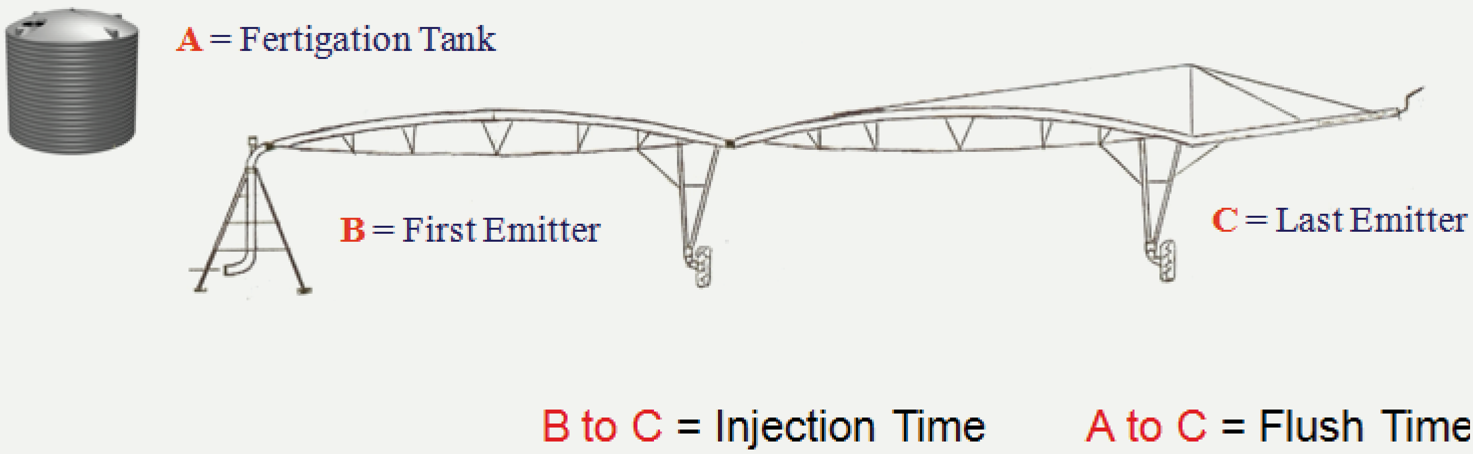
B = First Emitter

C = Last Emitter

Injection time – B to C

Flush time – A to C

Chart 11: Schematic diagram of a centre pivot



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What do the times mean?

The fertiliser injection must take at least the same amount of time or longer than it takes for the fertiliser to move from the first emitter to the last emitter. If the injection duration is shorter then not all the areas in the irrigated field will receive the same amount of fertiliser. The uniformity of fertiliser will be uneven with parts of the crop receiving more than others.

Once the fertiliser is injected the system needs to be flushed for the correct amount of time. This is the same as the time it takes for fertiliser to get from the tank to the last emitter/sprinkler. If the irrigation system is not left running for this time or longer, fertiliser will remain in the main / sub-mains and not be correctly distributed in the block. Worse still, fertiliser (salt) will be left inside the system which may cause corrosion.

APPLICATION TIPS

The following application tips are provided with the objective of preventing contamination of nearby water sources, and to ensure good OH&S and handling practices.

- Maintain a neat storage, mixing and injection area. This promotes safe handling, and facilitates early recognition and clean-up of any spills and leaks.
- Prevent drainage from the mixing area into streams, dams or bores.
- Prevent back-flow from the irrigation lines into the water supply. This is more likely to occur where suction systems, on the inlet side of the pump, are used to introduce fertiliser solutions.
- Allow excess water to re-enter reticulated water supplies for use on other irrigated fields where the same crops are grown. Livestock should be denied access to tail-water to avoid any risk of urea or nitrate poisoning. This is also important for other reasons e.g. it is particularly important if pesticides have been used for which a nil Maximum Residue Level (MRL) applies to livestock products.
- Prepare fertiliser solutions as close as possible to the time of use. Do not allow to stand for an extended period of time e.g. overnight. This can help minimise precipitation and settling in mixing tanks in some instances.
- Inject fertiliser solutions upstream of filters, so that insoluble contaminants are screened out.
- Flush injectors and lines after use, to minimise corrosion and scale formation, and extend the life of gaskets.

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