Australian Government

Department of Agriculture, Water and the Environment

AUSTRALIAN Pork™

Sludge handling and management

Final Report
APL Project 2013/2409

Sludge Handling and Management - Producer information on pump selection and costs

June 2014

FSA Consulting
Eugene McGahan, Bradley Warren and Rod Davis
PO Box 2175
TOOWOOMBA QLD 435

Factsheet Development

Three separate factsheets have been developed, titled:

1. Sludge Pump Selection - provides criteria for piggery and feedlot operators to select the appropriate sludge pump to suit their requirements.
2. Sludge Pump Types - provides information on the two types of sludge pumps, centrifugal and positive displacement pumps
3. Commercial sludge pumps - provides information on a variety of commercially available pumps suitable for pumping piggery and/or feedlot sludge.

A copy of these factsheets is attached to this report.

These factsheets complement the other series of factsheets developed by FSA Consulting as part of APL Project 2012/1029 – Sludge Handling and Measurement. This project produced the following factsheets:

1. Characteristics and accumulation of sludge
2. Removal of sludge from ponds
3. Dewatering sludge

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Sludge Pump Selection and Cost Information
Fact Sheet Series
June 2014

Fact Sheet
Selecting A Sludge Pump

This factsheet provides criteria for piggery and feedlot operators to select the appropriate sludge pump to suit their requirements. For detailed information regarding the different types of sludge pumps refer to the 'Types of Sludge Pumps' fact sheet. For commercially available products refer to the 'Commercial Sludge Pumps' fact sheet.

Sludge Properties Influencing Pumping

Sludge is a mixture of water and solid materials (total solids (TS)). The TS component can be inorganic material (any materials such as debris, sand or rocks plus the ash component of organic wastes), slowly digestible organic material or dead microbial cell mass. The ratio of water to solids (TS content) can vary considerably.

The physical characteristics of the sludge or slurry are vital in determining the appropriate pumping method. Particle size distribution (PSD) and bulk density are important but the rheological properties have the greatest influence. Rheology is the study of the flow of matter, primarily liquid, under conditions in which they respond with plastic flow rather than deforming elastically in response to an applied force.

Several studies have been conducted into the rheological properties of piggery and feedlot sludge and slurry. Researchers found that resistance to pumping increased with increasing TS content and decreased with higher temperature. Sludge with a high TS content also causes more wear and tear on pumps and creates excessive flow resistance in pipes.

Figure 1: Sludge removal via pumping

- Effluent with a TS content <5% is easily pumped with conventional centrifugal pumps.
- Slurries with a TS content of about 5-15% TS can be pumped with various types of positive displacement pumps or centrifugal pumps with modified impellers (i.e. chopper pumps).
- Sludge with a TS content above 15% is virtually impossible to pump.
- Regular desludging of ponds will avoid TS concentrations exceeding 10%, making sludge removal easier.

What is a Slurry Pump?

There are two major categories of sludge pumps: centrifugal (dynamic) pumps where continuous energy increases the flow velocity of the fluid, which is later converted to lift or pressure; and positive displacement pumps in which periodically added energy directly increases pressure or lift.

Centrifugal sludge pumps differ in design from conventional centrifugal pumps due to the abrasive and corrosive nature of the sludge. Sludge pumps need to consider impeller size and design, type of shaft seal and the choice of materials. Centrifugal sludge pumps must have wider and heavier impellers to allow the passage of large solid particles. They also require special materials to prevent internal wear.

Improving Pumping Ability of Sludge

Guidelines for improving the pumping ability and avoiding settling and blockages include;

1. Avoid excessive dilution of the sludge, this ensure solids stay entrained in the mixture.
2. Maintain sufficient flow velocity, usually at least 1 m/s.
3. Ensure pipe diameter is sufficient, use quality pipe material and joints. Pipe diameter should remain consistent through whole system to prevent solids accumulation.
4. After sludge pumping, flush pipeline with clean water or digested effluent.
5. Use variable speed pumps to operate pump at speed best suited to sludge characteristics.
6. If using centrifugal type ensure impeller has chopper design to breakdown solid material.

Pump Selection

Correct pump selection is very important because pumps are designed to suit specific pumping conditions. The following steps should be used to select the appropriate pumps (Warman International Ltd. 2000). Refer to the 'Commercial Sludge Pumps' fact sheet for retail information.

1. Determine the flow rate, usually established by the volume of solids to be pumped and the proposed concentration of solids. The flow rate through the pump is directly proportional to pump speed, head to speed squared and power to speed cubed. It means that if the pump speed is doubled, then the generated head would generally need to be four times higher and the power consumption eight times higher.
2. Determine the static head, the vertical height on both the intake and discharge side of the pump.
3. Determine the pump head and efficiency corrections, which is determined by the average particle size of the solids (d_{50} mm, the theoretical screen size where 50% would pass and 50% would be retained.), the concentration of solids (% by weight) and the dry specific gravity of the solids (refer to Sludge Handling and Management Investigation Fact sheet series - Characteristics and Accumulation of Sludge for more information on sludge PSD).
4. Determine the pipe diameter, which will provide the optimum velocity to minimise friction, while keeping solids in suspension.
5. Determine the friction head loss. For TS contents greater than 2%, friction losses are from 1½ to 4 times the friction losses for water (Guyer 2011).
6. Calculate the total dynamic head.
7. Select pump type and materials from the supplier product catalogue.
8. Determine pump speed from the selected pump's performance curve.
9. Determine the required power, which allows the motor to be correctly sized.

Selecting a Centrifugal Sludge Pump

Some centrifugal pumps are specifically designed for pumping sludge from ponds, for example with an adjustable pump length or mounted to a tractor. The major factors to consider when sizing pumping equipment include the distance from the immediate storage to the field or drying bay and the average flow rate needed for the desired application rate. The solids are moved only when drag forces, generated by the faster water, overcome gravity forces. When this is not achieved, solids can settle and thus block the pipe. As a rule of thumb, the liquid velocity for pipe sizing needs to be greater than 1 m/s to keep the solids suspended.

The effect of particle sizes in the sludge has an impact when choosing a centrifugal sludge pump. Figure 2 provides a guide for choosing centrifugal pumps based on the median solid particle size. If the median solid particle size is above 15 mm the impeller, liner and casing need to be metal instead of elastomer material. For particles above 80 mm centrifugal pumps will not work and positive displacement pump types will need to be used.

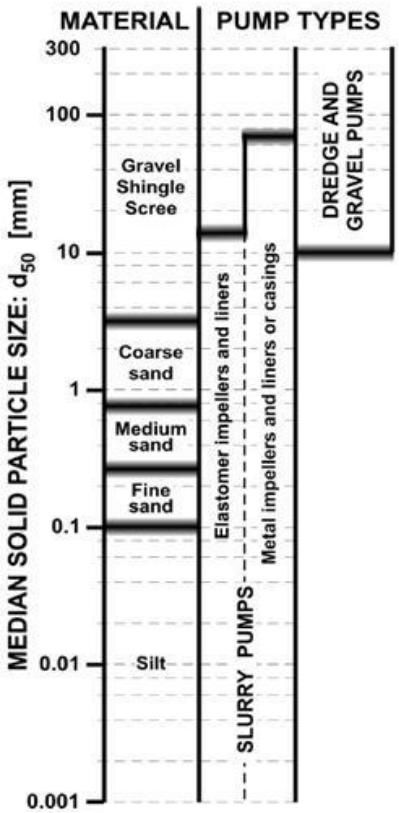

Figure 2: Particle Size Pump Selection Guide

Selecting a Positive Displacement Pump

Positive displacement pumps can be broadly categorised as either reciprocating or rotary. Reciprocating pumps include diaphragm pumps and plunger and piston pumps. Rotary pumps include progressing-cavity pumps, rotary vane vacuum pumps and lobe pumps. The selection of pump for a particular situation needs to take into account the variables specific to the site and application. Table 1 provides some general guidelines.

Table 1: General Selection Characteristics for Positive Displacement Pumps (Source: PDHengineer.com)

Parameter	Reciprocating pumps	Rotary pumps
Capacity	Low	Low/Medium
Pressure (Head)	High	Low/Medium
Maximum Flow Rate	10,000+ GPM	10,000+ GPM
Maximum Pressure	100,000+ PSI	4,000 PSI
Requires Relief Valve	Yes	Yes
Flow Type	Constant	Constant
Flow Characteristic	Pulsating	Smooth
Space Considerations	Requires More Space	Requires Less Space
Initial Costs	Higher	Lower
Maintenance Costs	Higher	Lower
Energy Costs	Lower	Lower
Liquids Recommended	Viscous liquids, dirty chemicals, tacky glue and adhesives, oil, and lubricating fluids. Specialty fitted pumps can handle abrasives.	Optimum for viscous fluids. Requires clean, clear, non-abrasive fluid due to close tolerances.

Key Points

- Sludge with high TS content (i.e. > 10%) is more difficult to pump and will increase wear and tear on pumps.
- Two types of pumps are suitable for sludge - centrifugal and positive displacement.
- Follow recommended guidelines for improving sludge pumping ability and when selecting a sludge pump for a particular situation. If unsure seek specialist advice from pump manufacturers.
- Centrifugal pumps
    - Advantages - low starting torques means they are less susceptible to blockages, better for long distances.
    - Disadvantages - can't develop high pressures, affected by fluid viscosity, impeller wear reduces performance over time.
- Positive Displacement Pumps
    - Advantages - multiple designs to choose between, generate high pressures, can pump material with TS 10-15%, long life expectancy.
    - Disadvantages - lower flow rates, can be expensive due to large installation requirement.

References and Further Reading

Guyer, J 2011, Introduction to Sludge Handling, Treatment and Disposal, Continuing Education and Development, Inc.

Warman International Ltd. 2000, Warman Slurry pumping handbook (Australasian Version), February 2000, Warman International Ltd, viewed 23 September 2009, < www.pumpfundamentals.com/slurry/ Warman_slurry_pumping.pdf >.

Other Fact Sheets in this Series

Types of Sludge Pumps

Commercial Sludge Pumps

Sludge Pump Selection and Cost Information
Fact Sheet Series
June 2014

Fact Sheet
Types of Sludge Pumps

This fact sheet provides information on the two types of sludge pumps, centrifugal and positive displacement pumps.

Pumping Sludge, Slurries and Effluent

There are two major categories of sludge pumps: centrifugal (dynamic) pumps where continuous energy increases the flow velocity of the fluid, which is later converted to lift or pressure; and positive displacement pumps in which periodically added energy directly increases pressure or lift.

- Effluent with a total solids (TS) content <5% is easily pumped with conventional centrifugal pumps.
- Slurries with a TS content of 5-15% TS can be pumped with various types of positive displacement pumps or specifically designed centrifugal pumps (i.e. chopper pumps).
- Once sludge exceeds 15% TS it is virtually impossible to pump unless diluted with water.
- Regular desludging of ponds prevents TS concentrations of >10%, making sludge removal easier.

Centrifugal Pumps

Centrifugal pumps are commonly used to pump effluent. They are equipped with a revolving impeller that converts electric energy from the motor into kinetic energy. The volute (stationary component) transforms kinetic energy into pressure energy, creating flow. A schematic of a centrifugal pump is shown in Figure 1.

Centrifugal pumps provide flow rates from a few litres to thousands of litres per second and can handle solid particle sizes from microscopic to sand. Their main limitation is that they cannot develop pressures higher than 1000 psi (7 MPa) even when they are arranged in series.

Impellers can be modified on centrifugal pumps to semi-open or vortex (chopper) so that slurries with up to 10% TS can be pumped. Pumps with modified impellers can also reduce blockages in long pipe installations, due to their open vortex design and lower starting torque. Blockages can also be avoided by equipping the pump with a vertical or inclined shaft. This reduces pump efficiency but allows it to handle semi-solid materials by minimising flow cavitation and solid blockages. An example of a centrifugal slurry pump with a chopper used to breakdown solid waste material is provided in Figure 2.

Figure 2: Centrifugal slurry pump with chopper

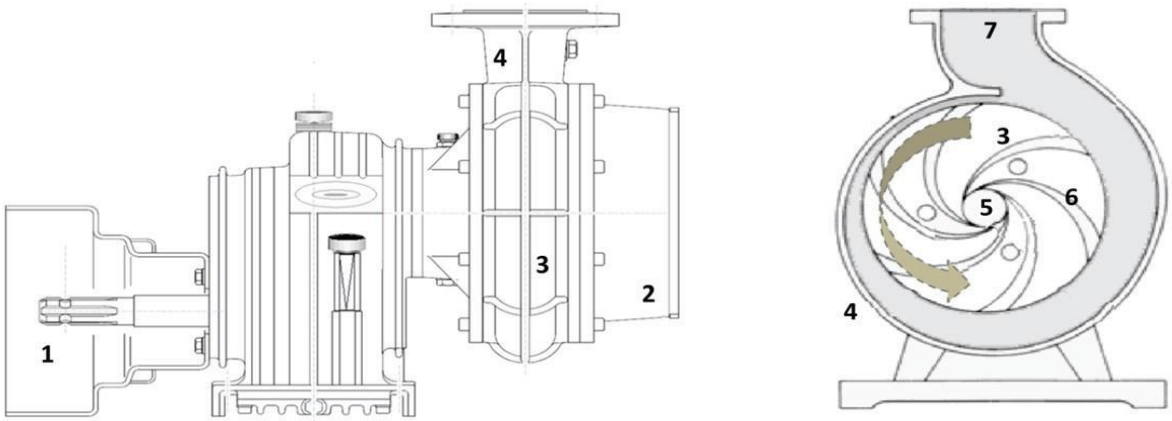

Figure 1: Centrigugal pump: 1 = power take-off, 2 = inlet with suction nozzle, 3 = impeller, 4 = volute case, 5 = suction nozzle, 6 = vane, and 7 = volute discharge (Brambilla et al. 2013)

Positive Displacement Pumps

Positive displacement pumps are either reciprocating (piston-and-diaphragm or piston-and-cylinder design (plunger or piston) with inlet and outlet poppet valves) or rotary (progressing-cavity pump, rotary-vane vacuum pumps and lobe pumps). They generate much higher pressures than centrifugal pumps but their flow rate range is limited from 50 to 1000 L/s, due to their large physical sizes.

Diaphragm Pumps

A diaphragm pump is a reciprocating pump also known as a membrane pump, air operated double diaphragm pump (AODD) or pneumatic diaphragm pump. They use a combination of the reciprocating action of a rubber, thermoplastic or Teflon diaphragm and suitable valves either side of the diaphragm (check valve, butterfly valves, flap valves etc.) to pump a fluid. Diaphragm pumps are self priming and are ideal for viscous liquids such as wastewater.

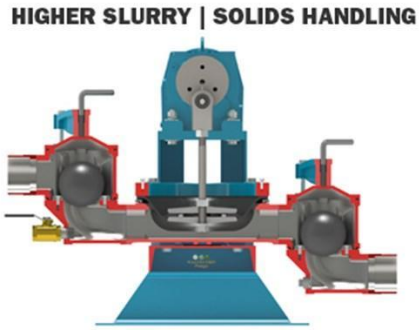

Figure 3: Schematic of GEHO-ZPM diaphragm pump

The essential elements are a flexible diaphragm and inlet / outlet valves. It is claimed that these pumps can deliver material with a TS content of greater than 15%. These pumps are expensive and require an extensive, permanent set-up, making them suited for heavy duty operations.

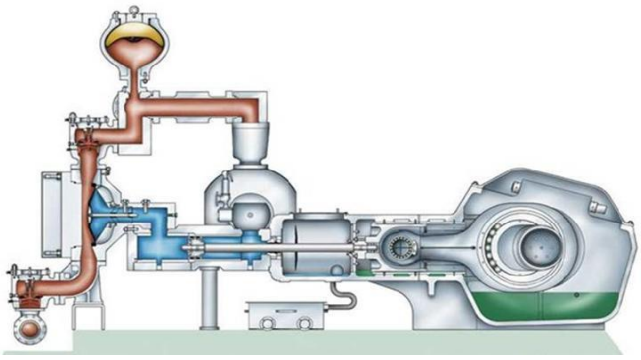

Figure 4: Schematic of Mud Sucker diaphragm pump

Plunger and Piston Pumps

In a piston pump the high-pressure seal reciprocates with the piston (Figure 5). In a plunger pump the high-pressure seal is stationary and a smooth cylindrical plunger slides through the seal (Figure 6). The design of a plunger pump allows it to be used at higher pressures 1000 - 30000 psi (70 - 2070 bar), compared to a piston pump. This type of pump is often used to transfer municipal and industrial sewage.

Piston and plunger pumps use a crank mechanism to create a reciprocating motion along an axis, which builds pressure in a cylinder or working barrel to force fluid through the pump. The pressure in the cylinder triggers the valves at the suction and discharge points. The volume of the fluid discharged is equal to the area of the plunger or piston, multiplied by its stroke length. The overall capacity of piston pumps and plunger pumps can be calculated with the area of the piston or plunger, the stroke length, the number of pistons or plungers and the speed of the drive. The power needed from the drive is proportional to the pressure and capacity of the pump.

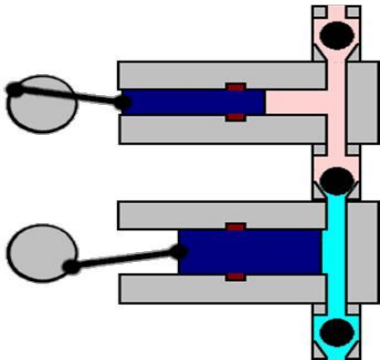

Figure 5: Schematic of piston pump

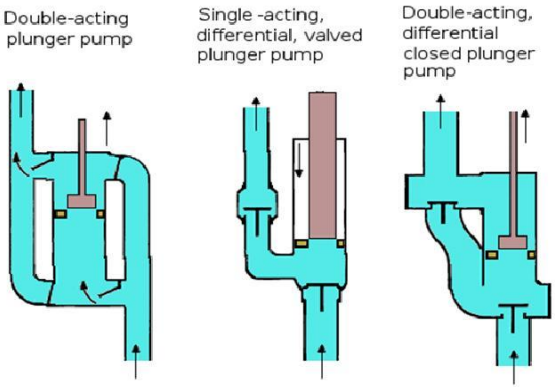

Figure 6: Schematic of plunger pumps

Screw Pumps (Progressing-cavity)

A screw pump is a type of positive displacement rotary pump and is also known as a progressing cavity pump. The screw pump consists of a screw rotor in a rubber stator (Figure 7). The rotor seals tightly against the rubber stator as it rotates, forming a set of fixed-size cavities in between. The cavities move when the rotor is rotated but their shape or volume does not change. The pumped material is moved inside the cavities. These pumps are used in fluid metering and pumping of viscous materials.

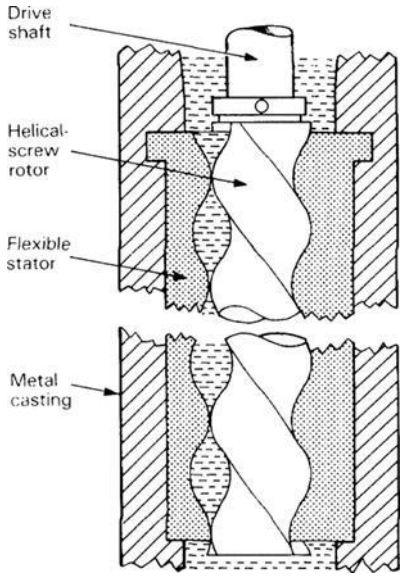

Figure 7: Schematic of screw pump

Vane Pumps

Vane pumps are self-priming and deliver a constant, smooth flow regardless of pressure variations.

A vane pump is a positive-displacement pump that consists of vanes mounted to a rotor that rotates inside of a cavity (Figure 8). In some cases, these vanes can be variable length and/or tensioned to maintain contact with the walls as the pump rotates. Rotary vane pumps are a common type of vacuum pump, with two-stage pumps able to reach pressures well below 100 psi.

Vane pumps are the most common type of pump used on agricultural vacuum tankers.

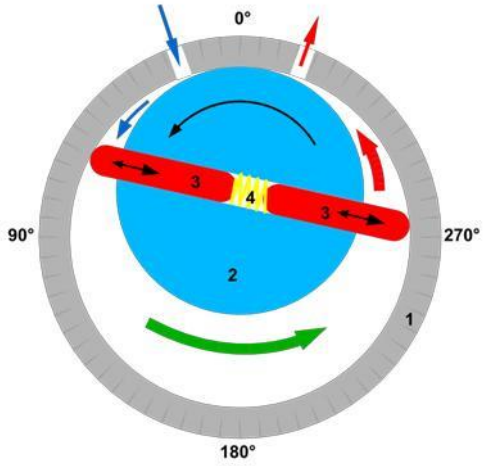

Figure 8: Schematic of vane pump

Lobe Pumps

Lobe pumps are designed with two or three shafts and are often used to pump material with a high solids content, 10-15% TS. These pumps have two or more wings that mesh together inside a housing made of two circular segments (Figure 9). The rotation of the lobes and their housing generate flow. These pumps have a fluctuating volume flow, which generates gentle pressure pulsations in the pipeline due to acceleration and deceleration of the flow. The design of the lobes allows for the pump to handle high solids content with minimal wear. Other advantages of these pumps include, reversible flow, and the ability to operate dry for long periods.

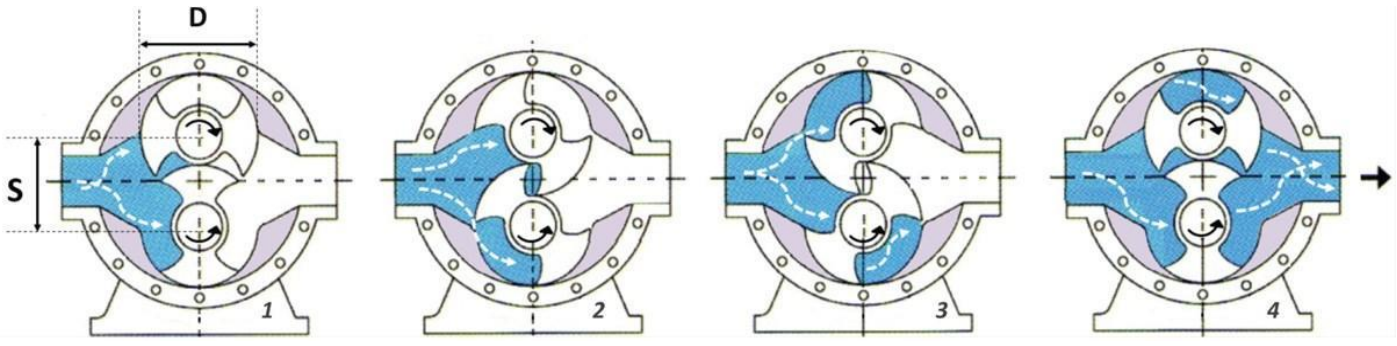

Figure 9: Example of rotary lobe pump and its operation (S = shaft diameter and D = tip diameter). Scimitar-shaped lobes are able to reduce build-up of particles between the rotors and the case.

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Fact Sheet

Key Points

· Two types of pumps, centrifugal and positive displacement, are suited for pumping sludge.

- Centrifugal pumps - continuous energy increases the flow velocity of the fluid, which is later converted to lift or pressure. Require a vortex (chopper) impeller to handle TS >2%.
    - Advantages - low starting torques means they are less susceptible to blockages, better for long distances.
    - Disadvantages - can't develop high pressures, affected by fluid viscosity, impeller wear reduces performance over time.
- Positive displacement pumps (diaphragm pumps, piston and plunger pumps, screw pumps, vane pumps, and lobe pumps) - periodically added energy directly increases pressure or lift.
    - Advantages - multiple designs to choose between, generate high pressures, can pump material with TS 10-15%, long life expectancy.
    - Disadvantages - lower flow rates, can be expensive due to large installation requirement.

References and Further Reading

Brambilla, M et al. 2013, 'Rheological properties of manure/ biomass mixtures and pumping strategies to improve ingestate formulation: A review', Transations of the ASABE vol. 56, no. 5, pp. 1905-1920.

Roos, C. J., 2007, A guide to pumping manure slurries in centralised biogas digester systems, Washington State University Extension Energy Program, U.S. Department of Energy

Wilson, K et al. 2006, 'Slurry transport using centrifugal pumps', Springer.

Other Fact Sheets in this Series

Selecting a suitable sludge pump

Commercial sludge pumps

Fact Sheet
Commercial Sludge Pumps

Sludge Pump Selection and Cost Information
Fact Sheet Series
June 2014

This fact sheet provides information on a variety of commercially available pumps suitable for pumping piggery and/or feedlot sludge.

Centrifugal Pumps

Centrifugal pumps are generally the cheapest option and are suited for smaller sludge removal operations. There is a wide range of centrifugal sludge pumps (chopper pumps) on the Australian market. Most manufacturers offer various designs including submersible and non submersible, impeller types and casing material types, all for a range of pipe diameters.

Non - submersible

Examples of pumps specifically designed for pumping sludge from ponds are listed in Table 1. They either have an adjustable pump length or can be driven by a tractor (Figure 1). Supplied by GEA Farm Technologies - *http://www.gea-farmtechnologies.com/au/en/*

Table 1: Example pumps from GEA

Pump	Description	Revolutions Per Minute (RPM)	Capacity (m^3/hr)
Agi-Pompe	To agitate, chop and transfer effluent containing fibrous material and high percentage solids	540 RPM (with 120 HP min), 1000 RPM (with 160 HP min)	Up to 4878
Super Pump	To handle thick manure slurry with a low chopped straw content	540 RPM (with 90 HP min), 1000 RPM (with 180 HP min)	Up to 4878
Articulated screw propeller agitator	Effectively mix sludge from the pond floor, large impeller for faster agitation without splash and less odours, optional side to side articulation	540 RPM (with 120 HP min)	

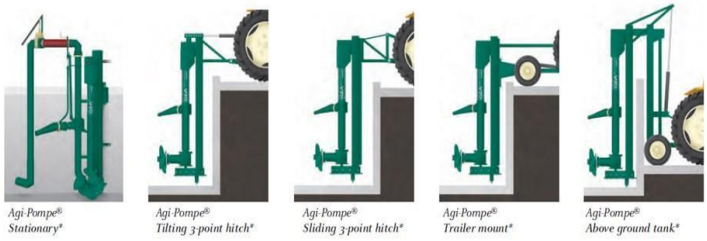

Figure 1: Five versions of Agi-Pompe and super pump of GEA

There are also heavy duty horizontal centrifugal sludge pumps available as shown in Figure 2. These pumps are designed for continuous pumping of abrasive material and are designed for a long life.

Figure 2: Slurry Pro heavy duty centrifugal sludge pump

Submersible

An example of a Flygt submersible centrifugal sludge pump is provided in Figure 3. There are a variety of these pump types readily available on the market.

Figure 3: Flygt submersible centrifugal sludge pump

Features of submersible centrifugal sludge pumps

- Cost effective and portable.
- Electrical motor
- Handle sludge with up to 10% TS content.
- Semi open impeller design to reduce blockages.
- Minimal number of parts and simple design.

Positive Displacement Pumps

Positive displacement pumps generally have a higher initial cost and are best suited for large-scale or continuous sludge removal operations with high TS content. For example, desludging a large pond with 10 years sludge accumulation. Regular desludging is recommended to avoid TS concentrations of >10% which make sludge more difficult to remove.

Diaphragm Pumps

Commercial examples of diaphragm pumps used to pump municipal and mining slurries include:

GEHO PD Slurry Pumps - *http://www.weirminerals.com/default.aspx*
Advantages are:

- Handle abrasive, corrosive and high temperature slurries.
- Can be used to feed biomass into digesters.
- Low maintenance requirements and operating costs.

Figure 4: Heavy duty industrial GEHO PD - ZPM Pump

Mud Sucker - *http://www.wastecorp.com/mudsucker/slurry-pump.html*

1. Solids crushing ball valve.
2. Cast iron fluid channel.
3. Santoprene diaphragms.
4. Pump sizes to suit 75 mm or 100 mm pipeline.
5. Pressure relief valve.

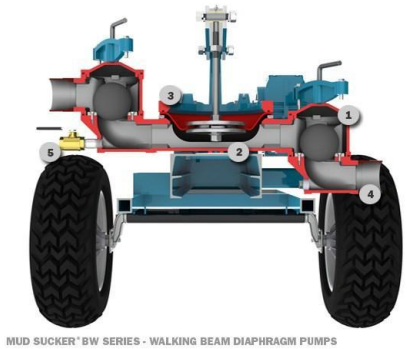

Figure 5: Walking Beam Diaphragm Pump - Mud Sucker BW Series

Sandpiper (AODD pumps) - *http://www.sandpiperpump.com/*

- Two diaphragms for handling solids.
- Portable and available in 25 mm to 100 mm pipeline.

Figure 6: Sandpiper heavy duty ball pump

Plunger and Piston Pumps

Commercial options for plunger and piston pump types suitable for pumping wastewater, include:

Komline-Sanderson Plunger Pump - *http://www.komline.com/docs/ks_plunger_pump.html*
Advantages are:

- ☐ Self priming, consistent flow rate.
- ☐ Can run dry without damage.
- ☐ Handles high solids concentrations.
- ☐ Low maintenance cost, replacement parts easily accessible.

Figure 7: Komline-Sanderson plunger pump

GEHO also provide crankshaft and hydraulic driven piston pumps - *http://www.weirminerals.com/products__services/ piston_pumps.aspx*

- Handle sludge's with moderate abrasiveness, medium to high viscosity and mild corrosiveness.

Figure 8: GEHO DHC valve operated hydraulic piston pump

Screw Pumps

Screw (progressing cavity) pumps are often referred to by the specific manufacturer or product names. Hence names can vary from industry to industry and even regionally; examples include:

Moineau (after the inventor, Rene Moineau) - *http://gb.pcm.eu/en/*
Advantages are:

- Pulsation free, low shear stress operation.
- Steady flow regardless of sludge viscosity or pressure.

Figure 9: EcoMoineau M progressing cavity pump

Mono pump - http://www.monopumps.com.au/

Advantages are:

- High pressure pumping over long distances.
- Gentle pumping action minimises shear and crush damage.

Figure 10: Installed Mono 'EZ strip' progressing cavity pump

Vane Pumps

Vane pumps are the most common type of pump used on vacuum tankers.

Battioni Pagani Pompe - *http://www.battionipaganipompe.it/bp/default.asp?sLang=EN*
Advantages are:

- Contains a exhaust/compressor to fill agricultural tanks and a centrifugal pump used for sludge spreading.

Figure 11: Battioni Pagani Pompe vacuum rotary blade pump

Key Points

- A large range of centrifugal sludge pumps are available from a variety of manufacturers. Some are specially designed for pumping sludge from ponds.
- Centrifugal pump types are usually cheaper and portable but will wear down faster than positive displacement pumps.
- The various design types of positive displacement pumps are effective at handling sludge with high TS content >10%.
- Positive displacement pumps are larger and most require a permanent installation.
- Piggery and feedlot managers choosing a sludge pump should review the manufacturers specifications and select a pump type that is best suited for their requirements.

Other Fact Sheets in this Series

Selecting a Sludge Pump

Types of Sludge Pumps