THE NORTH HIGHLAND COLLEGE

Duthchas Project

A report on domestic sewage system upgrades

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ERI

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1. Executive summary

The Environmental Research Institute of the North Highland College investigated domestic sewage systems on behalf of the Duthchas Project. The aim was to identify systems that would raise the standard of discharge effluent from domestic premises in the role of 'add-ons' to existing septic tanks. The Duthchas Project area has a varied topography and thus no one system is likely to fit all sites. Twelve different types of sewage systems were considered during the investigation. Three of the twelve studied systems fitted the criteria: Reed beds, Peat filters, and Wetland Ecosystem Treatment (W.E.T.) systems. All of these three systems are available in the far north of Scotland and all are proven technology. Should any of the septic tanks within the project area require replacement it may be cost effective to install a Rotary Biological Contactor (Biodisc) self-contained package treatment system.

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2. Introduction & Aims

The Duthchas project area boundaries are: Eribol; Strath Halladale; Kinbrace and Altnaharra. The project covers an area of approximately 1,200km^2 and includes some of the most challenging topography in the North of Scotland.

Within the project boundaries up to 1,700 homes have domestic sewage systems that are in need of upgrading. Some existing septic tanks discharge almost directly into the watercourse. This is causing concern to both residents and the Scottish Environmental Protection Agency (SEPA).

The topographical nature of the area is so varied that whilst soakaways and land drains have been utilised in some cases they are not a practical option for others. Geographically some properties lie in clusters whilst others have no near neighbours. This makes the problem particularly challenging for any potential developments in that no single type of system is likely to fit all cases.

It is the aim of this report to review the options available to the Duthchas project. It will recommend practical domestic sewage treatment systems that are both accessible to and within the budget of Duthchas project members.

3. Sewage – the cycle

Before looking at systems available in Scotland it would be well to take a look at the sewage itself and establish the general context within which sewage treatment occurs. The more one understands the rationale behind sewage treatment the less likely one is to inadvertently abuse or damage the treatment plant.

"Inanimate matter (e.g. mineral, gas and water) is constantly being incorporated into organisms and so taken out of equilibrium with its environment. Upon death the organisms' bodies undergo a process of decay – returning to equilibrium with the inorganic world (Fig.1)." (Grant et al. 2000). This cycle can be viewed as three phases of matter:

1. Mineral or inorganic
2. Organism
3. Organic matter

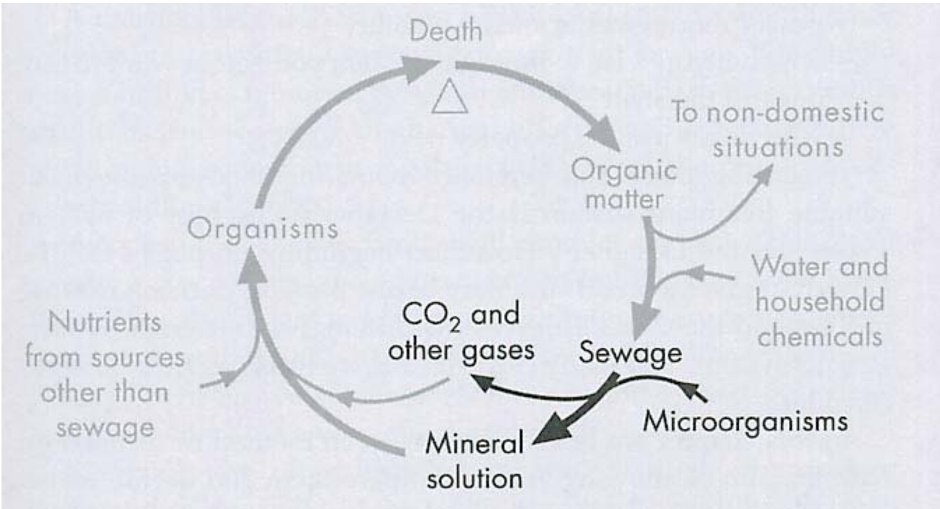

Fig.1. The sewage cycle

In very general terms sewage is a mixture of water and other types of organic matter. Domestic sewage also contains some level of detergents and other chemicals. For most of the UK this is all treated in purpose built sewage treatment plants maintained by the local water authority. For those people living in less accessible areas life is not quite so simple. Remote households have to consider what happens after 'The flush'.

We take in energy in the form of food. The waste is then discharged into our sewage treatment system. Given the correct conditions of heat, oxygen, water and organic matter our sewage becomes a feast for micro-organisms. These tiny creatures continue to break down the sewage until all that is left is a solution of minerals dissolved in water. It is this state that is aimed for by SEPA.

3.1. Treatment systems, an overview

Any good sewage treatment system must take into account a number of principal factors. The most important is to meet the standards laid down by the Scottish Environmental Protection Agency (SEPA) and the North of Scotland Water Authority (NOSWA). Once the regulations have been satisfied a number of other factors must be considered. The importance of these factors varies according to the individual situation.

3.1.1. Considerations/factors

- Available space
- Facilities available for maintaining the system
- Ecological sensitivity of the site
- System cost
- Power requirements of the system
- Whether the system is to be bought complete or constructed as a self-build project.
- Whether the sewage is from a single property or a number of properties
- Where the sewage treatment plant is to be sited
- What effluent discharge standards are required
- What climatic restrictions there may be in the locality
- What ground conditions are like at the site
- The site topography

3.2. What is sewage?

Sewage is made up of the following constituents:

- *Screenable solids* –Lumps of material measuring from 25-50mm (1-2 inches) in diameter that can be removed from the water by coarse screening. For example lavatory paper, food particles nappy liners and other non-biodegradable items.
- *Non-screenable solids* – Small particles, less than 25mm in diameter, mainly in suspension such as bacteria, faecal particles, fats, oils and soaps.
- *Dissolved material* – which may contribute to the colour of the water but not its cloudiness. These consist of organic matter such as proteins, carbohydrates and fatty acids and inorganic ions such as ammonium, chloride, nitrate, nitrite, phosphate, etc.

3.3. Why treat sewage?

The micro-organisms which break down sewage are extremely efficient at obtaining and using oxygen. If you ran a pipe from your house directly into a watercourse and flushed raw sewage into it, the organic matter would be broken down. However, the micro-organisms would use up huge amounts of oxygen in the process, suffocating aquatic life and causing the food web to fail.

Organic matter uses oxygen when decomposing:

- Thus a measure of the organic matter in a body of water is given by measuring the amount of oxygen being removed from that water during decomposition. This Measurement is known as the Biochemical Oxygen Demand (BOD). BOD is a measure of the dissolved oxygen consumed during the biochemical oxidation of organic matter present in a substance. When the decisions about standardised tests were being made it was agreed that the BOD incubation period should last for five days, this being the average time taken for sewage to reach the river mouth of an average British river.
- Another easily measured quantity is the amount of matter present in the water. This is known as the Suspended Solids (SS).
- BOD and SS are the two sewage qualities most commonly measured by the authorities.
- When the sewage sample contains compounds that are not degradable by micro-organisms, or not biologically degraded within the five day incubation period the Chemical Oxygen Demand (COD) test is used. Chemical oxygen demand (COD) is a measure of the amount of oxygen required to chemically oxidize organic matter in a sample.
- Ammonia is perhaps the next most important substance to remove from sewage. Domestic waste can produce large amounts of ammonia, a substance to which many aquatic organisms are highly sensitive.
- Sewage treatment removes potentially pathogenic materials and organisms such as bacteria, viruses, worms and chemical compounds.

When untreated sewage is discharged into a watercourse it will:

- Remove oxygen
- Kill plants
- Cause a risk to health
- Create a nuisance

Prevent its use for:

- Water supply
- Crop irrigation
- Fisheries
- Recreation

3.4. Stages of treatment

- *Preliminary treatment* – Physical removal of screenable solids. In larger systems this is achieved by passing the sewage through a screen of 25-50mm diameter or net of similar gauge. In the small domestic system a septic tank is normally used for this stage of the process. The primary treatment stage removes 30-50% of the BOD and SS. In systems designed for a population greater than 500 persons some form of preliminary treatment is required. At this stage a lot of sludge is created. This is removed from the settling tanks by either manual or automatic means. It is unlikely that the Duthchas project will need to consider preliminary treatment other than settlement in the septic tank unless planning larger developments for housing clusters such as Skerray.
- *Secondary treatment* – removes most of the remaining BOD (mainly soluble organic material) and SS. At this stage micro-organisms break down the organic material in the sewage. This biological stage is about optimising environment in which breakdown can happen. After initial settling the sewage still contains a large amount of biological pollutants. The biological treatment stage purifies the sewage by removing dissolved organic material so that the effluent can be safely discharged in to the environment. This takes place primarily in the septic tank and continues in the filter bed. The filtration area will be colonised by creatures such as protozoa, worms and insect larvae, all of which help to recycle the nutrients and water.
- *Nitrification* – is the transformation of ammonia to nitrate. Nitrifaction happens in the latter stages of sewage treatment and is performed by a few specialist bacteria.
- *Tertiary treatment* – refers to any or all of the following: Removal of further remaining BOD and SS; removal of nutrients such as nitrogen and phosphorus compounds and removal of pathogenic organisms. Tertiary treatment involves taking the effluent through a further biological, physical or chemical stage such as a reed bed.

4. The systems

- Septic tank systems
- Percolating filters
- Land drains or drainfields
- Mounds
- Seepage pits and soakaways
- Reed Beds
- Peat systems
- Activated sludge systems
- Rotary biological contactors
- Activated sludge systems
- Other packaged systems
- Wetland ecosystems

4.1. Septic tank sewage treatment systems

4.1.1. What are they?

Septic tank systems were first introduced into the UK in the early 1800s and were initially used for the treatment of sewage at large country houses as a replacement for the less-than-sweet smelling 'privies'. In addition to the septic tank many soon added filter beds and humus tanks to further treat the sewage before discharging the effluent to the watercourse. By the early 1900s the septic tank system enjoyed widespread acceptance and was to be found in many small rural properties. Recent environmental legislation has made the septic tank alone insufficient and further treatment is usually required before effluent can be discharged from the tank into the watercourse.

The most common type of septic tank system consists of an underground tank connected to a soil treatment system, usually a land drainage system, drainfield, mound, or at-grade system.

4.1.2. How do they work

Untreated wastewater from the house flows into the septic tank where the solids settle out from the liquids. Some solids such as soap scum and fats float to the surface of the tank and form a scum layer. The heavier solids such as human and kitchen wastes settle to the bottom of the tank as sludge. Bacteria in the tank help 'digest' these solids. The remaining liquids flow out of the tank to a land drainage or drainfield system before finding their way into the watercourse. Baffles built into the tank physically hold back the surface scum and prevent it from entering the drainage system where it could clog the soil and prevent the free flow and filtration of liquids from the tank. It is advisable to monitor the level of solids in the tank to ensure that they do not wash out into the soil system. It is generally recommended that tanks be emptied annually to prevent excessive sludge build up.

In the UK the standard septic tank used to be constructed from brick or stone and latterly concrete (fig.2). The inlet pipe into the first of two chambers forms a dip pipe that ends 450mm (18 inches) below top water level (TWL), the chamber being a minimum of 1500mm (5 feet) deep from TWL. The dip pipe is normally 100mm (4 inches) diameter and has a vertical pipe for rodding. The first stage section usually measures W width x 2W length. The pipe joining the first to the second section also ends 450mm (18 inches) below TWL, the chamber also being 1500mm (5 feet) deep from TWL. Again, the dip pipe is 100mm (4 inches) diameter and has a vertical pipe for rodding. The dimensions of the second chamber are usually W width x W length. The outlet pipe from the second chamber also consists of a dip pipe but the bottom of the pipe is a minimum of 300mm (12 inches) below TWL. There should also be vent pipes from the first chamber (preferably both chambers) to vent any gases rising from the sludge. For safety reasons all septic tanks should be provided with a strong cover.

Modern tanks are constructed from tough glass reinforced plastic (GRP) and are commonly spherical in shape with a narrow neck to accommodate a manhole cover. They contain baffles that help settle out the solids quickly and efficiently. They are easily made and readily available throughout the developed world. Being of lightweight construction, care should be taken to ensure that these tanks do not rise out of the ground when emptied, due to high water levels in the ground.

The effluent from a septic tank typically contains about 70% of the polluted matter, hence the need for further treatment before discharge to any watercourse.

4.2. Maintenance of septic tank systems

4.2.1. Important facts

The three most important things to remember about any septic tank system are:

1. *Do not overload the system.* Exceeding the capacity of the system causes surface discharges. These discharges are a health hazard and a threat to the local watercourse.
2. *Measure the sludge depth and scum levels regularly.* Empty at least annually or more frequently if the build up of scum and sludge threaten to discharge in to the drainage system.
3. *Never put strong or hazardous chemicals into the system.* Septic tanks are designed to cope with everyday household domestic sewage. They will not cope with substances such as paints, solvents, oils and pesticides. These will kill the bacteria in the tank and render it useless. Furthermore, these chemicals can flow through the soil and seriously pollute the local groundwater.

4.2.2. Tips for keeping a healthy system

- Keep grease out of the system, it inhibits the bacteria which digest the sewage
- Do not flush paper products other than toilet paper.
- Do not spend money on septic tank 'starters' or 'cleaners', they are not necessary. Bacteria present in human waste is all that is needed to 'start' the system.
- Waste disposal machines require a larger septic tank and more frequent emptying than normal. It is better to compost kitchen waste.
- Avoid driving vehicles over the land used for septic tank drainage. Vehicles compact the soil and reduce its capacity to drain.
- Roof drains and surface water drains can cause sludge to be washed out of the tank into the drains. Surface water requires no treatment and should not be directed into the septic tank.
- Laundry wastewater contains soaps, dirt and grease and should never be used for surface discharge.
- Low flow shower heads and dual flush toilets help reduce the amount of waste water entering the septic tank.

4.2.3. Some causes of problems in the septic tank sewage system

- **Photography.** Silver nitrates can be problematical.
- **Garden weedkillers.** These contain paraquat, sodium nitrate and arsenic in varying concentrations.
- **Drain cleaners.** Have sulphuric acid as a base.
- **Paints and wood preservers.** May contain lead and phenols.
- **Floor and brick cleaners.** Most have a hydrochloric acid base.
- **Antifreeze.** This contains ethyl glycol.
- **Engine oils and hydraulic fluids.** The oils mask biological growth.
- **Bleach.** Contains caustic soda.
- **Laundries.** Detergents and surfactants severely inhibit treatment.
- **Dish washers.** These contain surfactants, caustic sodas, dyes and alcohols.
- **All-purpose cleaners.** Contain sulphonates and amides.
- **Heavy-duty cleaners.** Contain sodium hydroxide and potassium hydroxide.
- **Food processing.** High starch content can inhibit treatment.
- **Textiles.** Contain sodium hydroxide, acids and dyes.
- **Laboratories.** Discharge chemicals of all types.
- **Insecticides and fungicides.** Can contain mercury.
- **Paper and paper mills.** Waste from these sources contains bleaches, starches and dyes.
- **Dairy wastes.** Cause oxygen reduction in wastes and may contain cleaning chemicals.
- **Greases.** Cause blockages and have a masking effect on bacterial growth.
- **Petro-chemicals and resins.** Contain carbons and other chemicals that may inhibit treatment.

4.2.4. Symptoms of an overloaded system

- Sluggish toilet flushing
- Plumbing backups
- Gurgling sounds in the plumbing
- The ground is wet and boggy over the treatment system area
- Foul odours (tank/drains not vented or not emptied frequently enough)
- Low spots in the area over soil treatment system
- Tank rapidly refills after emptying (Water running back into tank from drainage system)

Every litre of water entering the septic tank system must be processed through the soil treatment system. The soil system has a limited capacity to treat effluent. With good septic tank habits the system will last for many years.

Not all sites are suitable for septic tank systems. Type and porosity of the soil is of primary concern when considering a new septic tank system. Soils that are too coarse or too fine will limit the effectiveness and efficiency of the treatment system. The depth of the seasonally high water table and type of bedrock must also be taken into account. Some of these problems may be overcome by altering the design of the system but generally speaking septic systems cannot be placed in areas where the depth of bedrock or the water table is less than 900mm (3 feet) from the ground surface. The size of a septic system is determined by the number of people in the property, usually expressed in terms of bedrooms assuming two persons per bedroom and the percolation rate through the soil on the property.

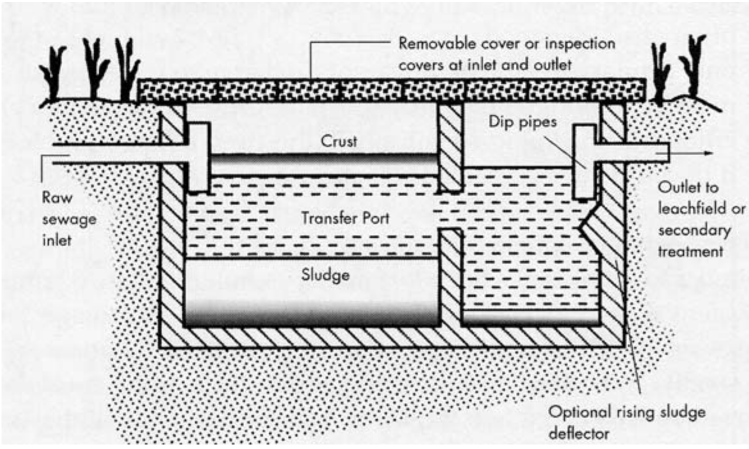

Fig.2 Septic tank

4.3. Percolating filters

Percolating filters consist of a container, usually around 2m (6 feet) in diameter. The container is filled with furnace clinker or stones known as the 'media'. Liquid sewage effluent is distributed, usually via a rotating arm (fig.3), over the media and drains freely from the base. Sewage clings to the media forming a thin nutritious layer upon which micro-organisms thrive. This process forms a slimy coating on the surface of the media, known as the 'biofilm'. Microbes in the biofilm digest the organic matter and hence clean the water. As the film thickens the inner organisms die and the film sloughs off to be settled in secondary settlement tanks. These systems are more suited to large communities than the domestic situation.

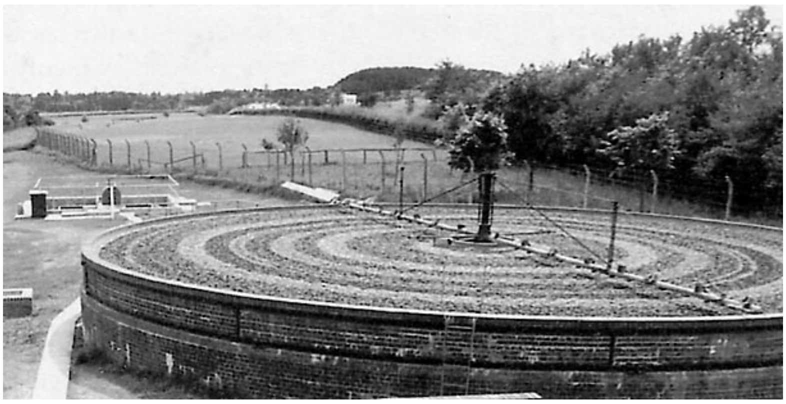

Fig.3 Percolating filter

4.4. Land drains or drainfields

4.4.1. What are they?

This is possibly the most important part of any septic tank system. Land drains and drainfields are underground soil treatment systems. They receive the partially treated sewage from the septic tank. The soil on site must be suitable for a drainfield to work. A percolation test should be performed before instalment of any drainfield or land drain system. Details of how to perform a percolation test can be found in section 5.6 of this report. It is best policy to employ a professional for this task but it is within the ability of the average person to do a preliminary test.

4.4.2. How do they work?

The drainfield is connected to the tank via an underground pipe. The drainfield may consist of trenches or a seepage bed. The bottom of the trenches should be a minimum of 900mm (3 feet) above the seasonally high water table or bedrock. In some areas clay prevents free drainage of the soil. In such areas land drains and drainfields should not be used.

In a land drain or drainfield wastewater moves from the tank into perforated pipes that are bedded on, and surrounded in, gravel-filled trenches (fig.4). These pipes are laid on a gradient of roughly 1 in 200 to enable the effluent to disperse along the whole length of pipe run. Pipe perforations should be larger than 6mm (¼ inch) to prevent the effluent from forming a biomass, which would block the system.

From the pipeline the pathogens, nutrients and organic material are dispersed into the gravel and are neutralised as the liquid moves through the soil. In a trench system a series of drop boxes fill and release effluent into the next trench in line. Seepage beds are gravel-filled excavations similar to trenches but greater then 900mm (3 feet) in width. Seepage beds should only be considered when the treatment area is both flat and limited in size.

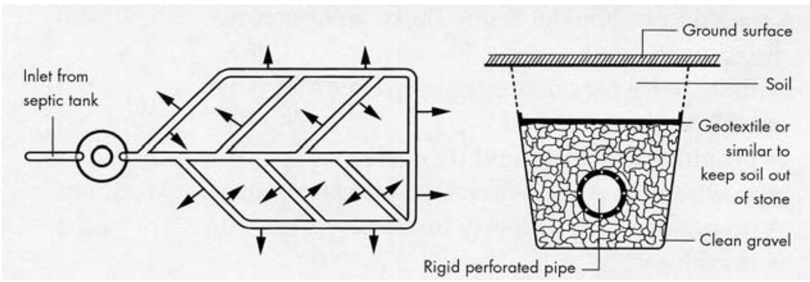

Fig.4 The drainfield

4.5. Mounds

4.5.1. What are they?

A sewage treatment system mound is an elevated sewage treatment system. Sand and gravel are used to raise the system so that it is at lest 900mm (3 feet) above seasonally high water table or bedrock. The size, shape and height of each mound must be carefully designed to ensure even distribution of the septic tank effluent throughout the mound.

The mound design must address:

- plot size
- local topography
- amount of sewage to be treated
- percolation rate (rate at which water flows through the soil)

4.5.2. How do they work?

Liquid from the septic tank is collected in a separate tank and pumped under pressure to the mound. This is done in small doses to allow time for the mound to process the effluent. Mounds are easily landscaped and are effective when properly designed.

An at-grade system is also an elevated sewage treatment system, but instead of clean sand it used drainfield rock as its distribution medium. The size of an at-grade system depends upon the amount of sewage to be treated and the percolation rate of the soil. At-grade systems also require a small pumping station or storage tank to pressurise the system for adequate distribution across the medium.

Mounds are popular in the USA. According to consulting engineer Ted Smith (Johnston Smith consulting Ltd.) they have a reputation for blocking and having to be dug out and replaced on a regular basis, raising the problem of contaminated material disposal.

4.6. Seepage pits and soakaways

4.6.1. What are they?

These systems have been used in the past and involve discharging a septic tank into a deep, cylindrical pit that is open at both sides and bottom. These pits were sometimes built using honeycomb bricks or perforated concrete walls.

4.6.2. How do they work?

The pit is filled with stones or gravel and capped with a manhole cover. Percolation in the strata throughout the entire depth of the pit must be good otherwise the result is a deep pit filled with effluent. These systems should never be used in poor percolation areas. It is unlikely that this system would be viable in the Duthchas area due to the predominance of shallow soils.

4.7. Reed beds

4.7.1. What are they?

It was noticed that the lower reaches of the Volga River was not as polluted as it should have been given the amount of heavy industrial discharge along its banks. Investigation revealed that bacteria in natural reed beds were feeding off the effluents and that aqautic plants were aerating the water through their root systems. Recently, reed beds have become a popular method of treating sewage here in the UK.

Reedbeds are an environmentally benign form of sewage treatment developed in recent years. They have the advantages over other most other systems in that they are living ecologies and not mechanical devices.

The basic design consists of a septic or settling tank where solids are separated from liquids and a bed of gravel and reeds, lined with a waterproof material. The liner is filled with gravel into which reeds of the species Phragmitis australis are planted. An inflow pipe from the settling tank feeds the separated effluent into the reed bed. The outflow pipe puts the treated effluent back into the environment.

There are two basic methods of using reedbeds for cleaning water:

- *The Kickuth system.* The Kickuth has a horizontal flow of wastewater through an artificial bed of gravel and reeds.
- *The Seidal system.* In which the sewage effluent is spread over a bed of reeds overlying gravel with a vertical flow.

It is of course healthier to treat the sewage at source with dry composting toilets and a separate greywater system but such systems are unpopular in the UK. The reed bed system offers an alternative and is readily adapted for use in conjunction with septic tanks.

4.7.2. How do they work?

They utilise the natural processes found at work around the roots of marshland plants. The bacteria living in aerobic conditions around the roots feed upon the harmful pathogens in the water, rendering the liquid healthier in the process.

- Small particles of sewage that don't get separated off as sewage sludge (suspended solids) are aerobically composted by the above ground layer of straw formed from dead leaves and stems.
- Wastewater is treated by the bacteria living on the gravel surfaces.
- Oxygen from the atmosphere passes into the reed leaves, down their stems and along their hollow root system. It then passes out into the surrounding effluent aerating as it does so. This is the sole means of oxygenation in the Kickuth system, but the Seidal system also relies on oxygenation from the air in the gravel. The Seidal system is not unlike the conventional circular clinker beds with a rotating arm feeding the effluent into the reed bed.
- The roots of the reeds spread both horizontally and vertically forming a network of hydraulic pathways permitting a flow through the system.

4.7.3. Types of reed bed

There are two types of reed bed to be considered:

- The horizontal reed bed
- The vertical reed bed

The main type of horizontal reed bed employed in the UK is the 'subsurface flow' system (refer to diagrams in appendix I). In this system the effluent from the septic tank is delivered into a 'v' section of the bed from where it flows horizontally through a bed of gravel which has been planted with the reed Phragmitis australis. The outlet pipe is situated at the opposite end of the bed to the inlet pipe. This system can be likened to a domestic bath, filled with gravel and planted with aquatic plants. As you top up the bath, water overflows at the far end. Thus, a depth of water of roughly 50cm (2 inches) is maintained in the bed, unlike the alternative free draining vertical bed. Standing water means that less oxygen is available for aerobic treatment. However, the lower levels of oxygen create ideal conditions for nitrogen removal from treated effluent.

The vertical reed bed is also planted with reeds. The difference being that the vertical bed is fed effluent on its surface from where it filters down through the gravel medium and out at the base.

4.7.4. Vertical Versus horizontal reed beds

Vertical reed bed		Horizontal reed bed	
Pros	**Cons**	**Pros**	**Cons**
High levels of treatment possible	Requires fall of at least 1.5m (4.8 feet)	Hundreds now working in UK	No major problems or disadvantages
DIY possible	Sensitive to hydraulic overloading	Becoming established technology	
Needs no power if gradient available	High cost unless DIY installation	Low cost	
Can be attractive		Natural appearance	
Simple maintenance		Needs almost no fall	
Will work before plants are fully established		Good pre-discharge buffer	
Robust		Good pathogen removal	
Smaller surface area than horizontal bed		Minimal maintenance	
		Robust	
		DIY possible	

Table 1. Vertical Vs Horizontal reed beds

Note: Reed beds should be sited not less than 15 metres from any dwelling.

4.8. Frequently Asked Questions About Reed Bed Sewage Treatment Systems

1. *Do they smell, and produce malodours?*

Not if they are correctly designed to cope with the maximum loading from the site.

2. *Will we see the sewage on the reed bed?*

The reed beds are designed so that the liquid flows through the bed where the roots exist, not over the top. Very occasionally in the early years of the reeds' growth, it may be advisable to temporarily flood the bed to rid it of weeds, but after these early periods this will not be necessary.

3. *Do the reeds need cutting down?*

The reeds, once grown do not require to be cut down and they will control their own growth.

4. *Why is it necessary to fence the reed beds in?*

This is essential to stop animals, particularly rabbits, eating the roots (which they find irresistible) and people from walking on or interfering with the reed bed.

If pumping is required why is it necessary to have two pumps?

In any system with moving parts it is always essential to have a standby system readily available, so that in the event of breakdown of the mechanical component the standby system will come into operation automatically, thereby ensuring continuity of sewage treatment.

5. *Will the maintenance costs of the system be the same as a conventional system of treatment*?

Generally the maintenance costs will be reduced. Over a long period, correctly designed reed beds have been shown to have considerably less operational costs than more highly mechanised systems.

6. *Are there any problems with reed bed systems?*

The main problem with reed beds is that they do require large areas of land, compared with a conventional or packaged sewage treatment works. However provided this land is available, on the whole they produce far less problems than other systems.

7. *What about discharging chemicals into a reed bed treatment system?*

A reed bed system will have the same constraints as any other system in as much as the discharge of certain chemicals must be restricted.

4.9. Commercially installed reed bed systems

Fig.5 Unobtrusive complete horizontal and vertical reed bed sewage treatment system installed at a hotel and serving a population of 24.

Fig.6 Attractive horizontal and vertical reed bed sewage treatment system followed by a pond (foreground)

Fig.7 Horizontal reed bed treatment system serving a Population of approximately 15 persons.

(FAQs and Figs 5, 6 & 7 courtesy Johnston Smith Consulting Ltd.)

4.10. Photographs of a local Horizontal Reed Bed.

Fig.8 View from the road

Fig.9 View of the reeds (November)

Fig.10 The sample chamber

4.11. Peat Systems

4.11.1. What are they?

The absorption and odour control of peat has been known since ancient times. In World War I the scarcity of cotton led to its substitution by peat moss for use as dressings in field hospitals. In Finland, treatment of wastewater from a town was achieved by pumping raw sewage to a large storage ditch in nearby peatland. The wastewater percolated through the peat to intercept ditches 20 metres away. The reported removal of phosphorus was 82%, nitrogen 90%, BOD 95% and pathogenic bacteria 99% (http://www.smhc-schl.gc.ca/). This system was installed in 1957 and is reported to be still functioning.

Today, a number of designs of peat filters are available, some requiring power and some working on gravity alone. The simplest form of peat filter is the Brooks design. In the Brooks system the peat bed replaces the drainfield. The pipe carrying the separated effluent liquid is laid in a bed of compacted sphagnum peat. Effluent leaves the septic tank and flows by gravity to a distribution box and then through distribution piping to the peat filter leaching bed. After the effluent filters through the peat it percolates directly into the soil below the peat bed for final disposal. The system is constructed on site.

There are at least two proprietary, modular peat systems available. Each module contains peat compacted to the correct density, complete with piping, packaged in a concrete or polythene box. These modules can be pre-constructed and delivered complete to site for installation. These systems can be supplied with or without an underdraining device to drain either directly into the soil or separate disposal area.

There are three basic types of peat:
1. Sphagnum
2. Reed-sedge
3. Woody peat

Of these sphagnum is the peat used in sewage treatment systems. The peat is air dried to ensure that its moisture content does not fall below 35%. If the moisture content falls below this figure the peat loses a considerable amount of its water holding capacity.

Other important parameters for peat used in wastewater treatment systems include:
- Von Post Degree of decomposition: H-4
- pH: 3.5 to 4.5
- Organic matter composition: >94%
- Nitrogen content: 0.5 to 1.0%

Note: Horticultural peat is not suitable for use in sewage treatment systems.

Peat treats sewage by three methods:
1. Physical filtration (structure of peat)
2. Adsorption (high ion exchange capacity of peat)
3. Microbial activity

4.11.2. How do they work?

The cool acidic environment and large surface area of the peat provides a favourable environment for the growth of microscopic fungi. Some of these fungi are able to assimilate all forms of nitrogen present in septic tank effluent. These fungi produce bactericides that contribute to the die-off of faecal coliforms and other bacteria.

The peat system functions like a conventional septic tank system except that the wastewater is filtered through 1m (3 feet) of peat before final discharge to the soil. Sewage from the house flows into a septic tank and the separated liquid then flows (either by gravity or pump) to the peat filter. Water eventually finds its way to the bottom of the peat filter where it then percolates into the soil for final disposal.

Peat filters efficiently remove faecal coliform bacteria, Biochemical Oxygen Demand (BOD) and total suspended solids (TSS). They also appear to be capable of producing a significant loss of total nitrogen in the finished effluent (http://www.smhc-schl.gc.ca/).

4.11.3. How the peat filter treats effluent:

Peat has a porosity[1] of about 95% and consequently a very high surface area. The surface area of peat is about 200m^2 per gram of peat.

The peat filter is a fixed film filtration system. It has unique chemical, physical and biological properties that contribute to its effectiveness as a filter. A combination of these properties helps keep the effluent in the filter for a long period of time allowing the wastewater to flow slowly over the surfaces of the peat fibres. This allows the effluent to:

- become aerated
- come into contact with the acidic chemical environment of the peat
- come into contact with the microbiological community inhabiting the peat.

- The moisture retentive nature of the peat enables the system to survive periods of disuse. It also helps keep the temperature reasonably stable which is probably why the system works well in cold conditions. Suspended solids are trapped within the spaces between the fibres producing a very low total suspended solids count in the final effluent. The peat fibres have a highly polar nature, creating an environment with a high cation exchange capacity. Many wastewater components become adsorbed to the surface of the fibres causing them to be trapped in the peat. Peat's highly porous nature and its high surface area make the peat bed a near ideal environment for supporting an aerobic microbiological community that performs the biological treatment of the sewage. "Treatment of the septic tank effluent is performed mainly by acid-tolerant bacteria and fungi living in the peat filter media. Pathogenic bacteria in the wastewater undergo significant die-off in the peat due to the acidic conditions and predation and competition from the natural microbiological community in the peat. It is also possible that the fungi in the peat itself releases antibiotic and phenolic substances that further act to reduce bacterial numbers." (http://www.smhc-schl.gc.ca/).

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[1] Porosity: The ratio of the volume of interstitial space in a material to the entire volume of the material.

4.11.4. Cation exchange capacity:

Cation exchange capacity is the total amount of cations (positively charged particles) that a soil can adsorb.

Peat contains lignin-like substances that are negatively charged. This allows peat to adsorb positively charged molecules. In other words, peat can hold molecules of substances such as ammonium, metals, pesticides some organic molecules and possibly viruses.

4.11.5. Performance:

A series of tests were carried out over a twelve month period in the USA. The results show that all peat filters consistently removed more than 90% of fecal coliform bacteria and many removed more than 99%. Reductions in BOD ranged from 80% to almost 100%. It was found that TSS in the treated effluent was reduced by as much as 92%. (http://www.smhc-schl.gc.ca/)

The producer of the Puraflo™ system, Bord na Mόna, monitored a number of their systems over a period of 18 months. The results show that values stated for the parameters listed in Table 2 are consistently achievable over a range of operating conditions (Irish Agrément Board).

Parameter	Concentration
pH	5-8
BOD (mg/l)	<15
TSS (mg/l)	<15
NH_3-N (mg/l)	<5
Nitrate-N (mg/l)	20
Total Coliforms elimination	>99.9%
Faecal Coliforms elimination	>99%
Pathogenic Bacteria	Absent

Table 2. Puraflo™ performance (Bord na Móna 1995)

4.11.6. System components:

The system consists of:

- *Septic tank.* Serving as a settling chamber.
- *Distribution box*. A small tank designed to split the effluent flow from the septic tank into a series of parallel flows. These flows are piped in to treatment tanks.
- *Treatment tanks*. Tanks filled with compacted sphagnum peat. Each tank measures roughly 3m (9 feet) long x 1,8m (5.8 feet) wide x 1m (3 feet) high.

4.11.7. Applications and suitability:

- **As a replacement system on a small plot.** A peat system needs less area than a conventional drainfield.
- **Near a body of water such as a loch.** Peat provides enhanced treatment.
- **For nitrogen removal.** Peat systems are able to remove nitrogen at similar levels to non-passive packaged systems.

One of the biggest advantages a peat system offers is that it is a passive system. It requires no mechanical aerators and does not depend upon electric motors and other

mechanical devices that are subject to wear or breakdown. In an area of uncertain power supplies, such as North Sutherland, this non-reliance on power is a bonus.
Fig 11 shows an eight module surface installation. Fig.12 shows a sub-surface installation of a similar size. A three-bedroom house requires, on average, only two modules. The enclosed system brochure contains full details of site and installation requirements.

Fig 11 Eight module Puraflo™ system

Fig 12 Sub-surface installation

4.12. Activated sludge systems

4.12.1. What are they?

These systems make use of processes used in larger municipal works. The domestic package versions usually work by bubbling air through the incoming sewage. Oxygen is used to rapidly degrade the organic matter. The process creates a slurry containing micro-organisms in their most rapid phase of growth, and thus ideal for sewage breakdown. Some systems have a single chamber for aeration and settlement whilst others have two or three cells. The compressors and filters require regular maintenance. The typical energy use of the system is greater than that of the Rotary Biological Contactor system (See below).

4.12.2. How do they work?

The slurry is allowed to settle, separating the active microbes as sludge from the relatively clean effluent. A portion of this active sludge is then returned to the incoming sewage, hence the term 'Activated Sludge System'. The remaining sludge accumulates in the system and is emptied as necessary. There are a number of variations of this system but all work on the same principle.

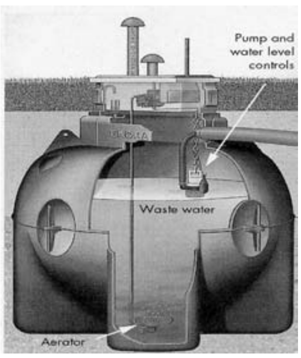

Fig.13 Activated sludge package plant.

4.13. Rotary biological contactor (Biodisc)

4.13.1. What are they?

Rotary Biological Contactor systems, also known as Biodisc systems, are supplied as packaged plants and can be bought 'off the shelf'. They can be installed very quickly, often in one day. They are compact, widely available and well established. All require an electrical supply. The system is self-contained and treats the sewage to a high standard using rotating discs as a sewage treatment medium. The effluent from these systems may, with SEPA consent, be discharged directly to a watercourse. Maintenance and emptying of sludge are required at regular intervals.

4.13.2. How do they work?

These systems contain a series of high surface-area polypropylene discs known as the Rotating Biological Contactor (RBC). The contactor is driven by a low energy electric motor. The disc supports a biologically active film of micro-organisms naturally occurring in domestic sewage.

The active film breaks down the sewage thus:

1. Waste water and sewage flows into the primary settlement are in the tank where the solids settle out. These solids have to be removed regularly as per septic tank.
2. The liquids then flow into the first stage biozone for treatment by the micro-organisms on the RBC.
3. Suspended solids then return to the primary settlement zone and the liquid is transferred to a second stage biozone for further treatment.
4. Any remaining solids settle out in the final settlement tank. The resultant liquid is safe to discharge into a watercourse.
5. Initial installation costs of this system can be high but under normal operating conditions the single home unit requires just one emptying per annum. The RBC is powered by a 60 watts electric motor providing low running costs. Some site preparation is required before this system can be installed but the system is supplied palletised and ready for rapid installation. If discharge is directly into a watercourse that watercourse <u>*must*</u> run for a full twelve months per year.

Fig 14 Installed RBC (CAT 2000)

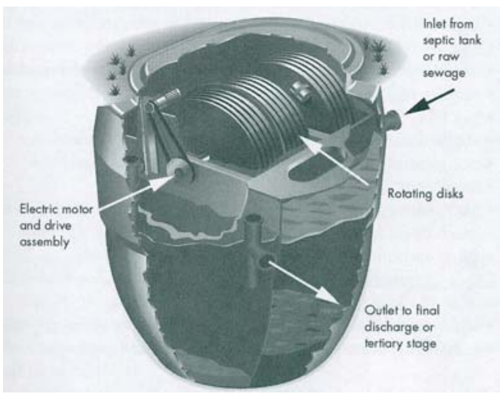

Fig.15 Cutaway diagram of RBC (CAT 2000)

4.14. Other package plants

4.14.1. Recirculating biological filters

These are similar to the percolating filters except that they use lightweight plastic media encased in a plastic shell. Effluent is circulated over the media by electric pumps.

4.14.2. Submerged biological filters

These systems are a hybrid of the activated sludge system and the recirculating percolation filter. The unit houses a biological filter through which effluent is passed and air is bubbled.

4.15. Wetland Ecosystem Treatment

4.15.1. What are they?

The idea of the wetland ecosystem treatment evolved through work with reed beds. These systems utilise a greater number of planted species than the reed bed including between 30-50 varieties of Willow and up to 40 species of wetland marginal plants. In domestic situations the system can be designed and planted as a garden feature including an ornamental or wildlife pond and bog garden (see appended species list). The system is usually employed for a population of between 1 and 60 persons but can be designed for up to 100 persons if required.

4.15.2. How do they work?

Wetland Ecosystem Treatment, or W.E.T. systems function by harnessing the innate ability of wetland ecosystems to absorb and transform the organic nutrients found in wastewater, converting these into plant biomass and soil.

Within the WET system the natural productivity of wetlands is harnessed creating a purification process which uses the wastewater as a resource, converting waste into yield. As wetlands are the most productive and species diverse ecosystems to have evolved, the potential for a high yield system is great.

The W.E.T. system consists of specially designed and constructed earth banks and ponds. As the wastewater flows through these soil banks, which are densely planted with wetland trees, marginal plants and aquatics, it is both purified by microbiological action and transpired by growing plants.

These systems can have a large volume and holding capacity. The total hydraulic load is lowered by evapotranspiration and the growing biomass absorbs the organic load. Coppicing the willows regularly keeps it at peak growth rate enabling the maximum absorption of organic matter as well as producing a crop of willow and reeds or rushes. In this system no gravel is used in their construction. Soil in the root zone acts as the filtration medium.

The basis of the purification process is, as with conventional treatment processes, microbiological. In W.E.T. systems the bacteria and fungi which transform the waste work in partnership with the root systems of the growing plants.

W.E.T. systems are designed for domestic waste and many types of agricultural and agro-industrial effluent, such as dairy farmyard and parlour washings, silage liquor run-off and pig slurry.

This system can be used to treat sewage from individual households of any size, or for treating the wastewater from farms, and small clusters of houses.

The system can be constructed in any shape and can, in some cases, be slightly smaller than an equivalent reed bed system.

4.15.3. Aims of the W.E.T. system

The three main aims of the W.E.T. system are:

1. The purification of wastewater with minimal or no energy use
2. The creation of a rich, multi-species ecosystem and wildlife habitat
3. The production of resources through the W.E.T. system's yield of willow and other commercial plants such as the reed mace.

4.15.4. Limiting factors

Willow growth rate is slow in the far North of Scotland therefore the production of a crop from this source is questionable but according to Biologic Design Ltd., other species of plant can be substituted to suit local climatic conditions.

The system requires a wetland situation. Soil may have to be imported to site in order to fulfil system requirements.

These limiting factors should be carefully considered before adopting this system.

Typically, the cost of building and installing a W.E.T. system is similar to that of a mechanical system such as a Rotary Biological Contactor. The system would initially have to be designed and built by professional contractors but with some degree of experience it is likely that a community could adopt a self-build policy, thus reducing the cost.

An application for the installation of a wetland system within the Duthchas project area has recently been lodged with SEPA and is receiving consideration at the time of writing.

Fig.16 Wetland system in U.S.A.

Fig.17 Wetland system in U.S.A.

4.16. Pros and cons of the systems

Pros	Percolating filter	Septic tank systems	Soakaways or drainfields	Mounds	Peat systems	Activated sludge systems	Vertical reed beds	Horizontal reed beds	W.E.T. systems	Packaged systems
Little to go wrong		✓	✓	✓	✓		✓	✓	✓	
Established technology	✓	✓	✓		✓		✓	✓	✓	✓
Low head loss		✓								
DIY possible		✓		✓			✓	✓	✓	
Usually underground		✓	✓			✓				✓
Prefabricated tanks rapidly installed		✓								✓
Low cost		✓	✓	✓			✓	✓		
Tolerant of peak loadings	✓								✓	
No power if fall available	✓		✓	✓	✓		✓	✓		
Provides treatment & disposal	✓		✓			✓	✓	✓	✓	
No foul odours			✓						✓	
Low maintenance			✓		✓		✓	✓	✓	
High level of treatment	✓				✓	✓	✓	✓	✓	✓
Robust	✓		✓		✓	✓	✓	✓		✓
Cons										
Often misunderstood		✓								
Primary treatment		✓								
Regular emptying	✓	✓				✓				✓
Stops working if mechanism fails	✓					✓				✓
Expensive	✓				✓	✓				
Needs fall 1.5-2m	✓						✓	✓		
Biosystem dies if unused	✓									✓
Tendency to clog				✓						
More space than packaged systems							✓	✓	✓	
Highly visible	✓			✓			✓	✓		
Water table >1m depth			✓							

Table 3 Pros and cons

4.17. Costs:

4.17.1. Costing systems for a 3 bedroom house

Cost estimates for the supply and installation of sewage systems will vary depending upon the type and local availability of any given system. The following estimates are intended as a *rough guide only*. Please note that installation costs will vary from property to property. The following prices assume a three-bedroom house. All prices are *exclusive* of VAT

4.17.2. Approximate system cost

The Septic Tank.

Typical Installation Costs:

Tank Cost = £500
Installation Cost = £500
Land drainage system (assuming 100 metres of drains) = £1500
TOTAL COST = £2500

Typical Maintenance Costs

Emptying once per year = 1000 galls x £90 = £90 per year.

The Modern Packaged Sewage Treatment Plant

Typical Installation Costs

Plant Cost = £2400
Installation Cost = £2000 (including power supply to unit etc.)
Land drainage system (assuming 100 metres of drains) = £1500 (or this may be a similar cost as an outfall pipe to a stream)
TOTAL COST = £5900

Typical Maintenance Costs

Emptying once per year = 1000 galls x £90 = £90 per year
Power consumption = say £50 per year
Maintenance = say twice per year at £50 = £100 per year
TOTAL COST = £240 per year

The Modern Reed Bed Sewage Treatment Plant

Typical Installation Costs, assuming contract build (DIY projects cost considerably less).

Total supply and Installation Cost = £5000 (including power supply etc.)
Land drainage system (assuming 100 metres of drains) = £1500 (or this may be a similar cost as an outfall pipe to a stream)
TOTAL COST = £6000

Typical Maintenance Costs

Emptying once per year = 1000 galls x £90 = £90 per year
Maintenance = say once per year at £50 = £50 per year
TOTAL COST = £140 per year

The Puraflow™ peat system

Typical installation costs

System including peat = £2,500
Installation up to £1,500
TOTAL COST £4,000

Typical maintenance costs

Emptying (if add-on to existing septic tank) £90 per year
60watt electric pump runs as required. Assume 3hrs per day @ 8p/unit = £5.25/yr
TOTAL COST £95

The W.E.T. ecosystem Treatment

Although the initial costs of this system are similar to the mechanical systems it is possible to self-build after gaining some experience of the system.

Installation £5,000
Self-build potentially £2,000

Typical maintenance costs

Gardening for the initial period of development. Gardening could be undertaken by the site owner at no cost.

PLEASE NOTE

- Prices quoted are approximate.
- Prices are based on telephone conversations with suppliers, all of whom stressed that their estimates should only be used as a guide.
- These prices do not include any fees, taxes or any costs for approvals.
- These prices are for a single property. Where there are more properties to be connected to a single system costs will vary.

5. Pollution prevention guidelines

(http://www.sepa.org.uk)

5.1. Septic tanks

- A septic tank is a two or three chamber system that separates solids from liquids, retaining the solids for sufficient time to allow sludge to form at the bottom of the tank where it is partially broken down. The liquid drains via an outlet pipe.
- Effluent from the tank normally drains into a soil soakaway system. This usually takes the form of a herringbone pattern series of perforated pipes laid into the ground.
- Before the effluent can be disposed of by soaking away into the ground, the area of land required for the soakaway must be determined by a Percolation Test. Areas of heavy clay, steeply sloping sites or sites where the water table is less than 1 metre (3 feet) below the bottom of the soakaway are not suitable.
- For domestic properties the capacity of a septic tank is calculated using the following formula: C = (180P + 2000) Where C = capacity of tank in litres and P = population served.
- The tank should be emptied on a regular basis, usually at least once per year. This task should be undertaken by a registered contractor.
- The septic tank soakaway area should be not less than 10 metres (32½ feet) from any ditch, drain or watercourse and preferably not closer than 15 metres (48¾ feet) from any dwelling. Vehicular access for tank servicing is required and should be catered for in the planning stage.
- Septic tanks and soakaways should not be sited near any well or borehole. The distance from the borehole depends upon individual site conditions but will not be less than 50 metres (162.½ feet).
- A SEPA 'Consent to discharge' will normally be required for any discharges to a soakaway.
- Clean surface water must be excluded from the septic tank system. Surface runoff will reduce the capacity of the system and may cause solids to flush out into the soakaway resulting in blockages.
- The only time a Consent to discharge may be given for a septic tank system discharging directly into a watercourse is when the dilution in the receiving watercourse is greater than four hundred times and the outfall gives no visible plume in that watercourse. Septic tanks that do not conform to BS6297;1983 will not normally be granted a consent to discharge.

5.2. Package sewage treatment plants

When a soakaway is not a viable option another method of treating the septic tank effluent must be sought. One such option is the 'Packaged Treatment' plant.

Packaged treatment plants are either self-contained units for the treatment of sewage or units that treat the effluent from septic tanks to a higher standard. They must be correctly installed in order to operate effectively.

Effluent from a package plant is normally suitable for discharge directly to a watercourse or into or onto land, where a direct discharge from a septic tank may be considered unsuitable because of pollution risks. Consent to discharge will usually be required for discharging into a watercourse. Consent may also be required for discharging into a soakaway. The consent will set quality and volume limits for the discharged effluent.

Most packaged plants require electricity for their operation and will require regular maintenance and de-sludging in accordance with the manufacturer's instructions in order to ensure their correct operation and effluent quality.

Most sewage systems use biological treatment. This is vulnerable to abuse. Check with the manufacturer's instructions on the use of cleaning materials such as bleach, and do not use the drains as a means of disposal for chemicals, oils and solvents. These chemicals will cause system failure. Care should also be taken to prevent the discharge of grease to the system.

5.3. Reed bed systems

Reed beds are specially designed and constructed plots with a gravel medium and an impermeable base which can be used to improve effluent quality. They have the advantage of no moving parts and require less maintenance than package systems. Reed beds rely on the ability of certain species of reeds to absorb and transport oxygen through their stem to the root zone, where it can be taken up by the organic material present in the sewage and hence effect purification of the effluent.

Before the installation of a reed bed SEPA should be consulted to determine whether it would be a satisfactory means of treatment given local conditions. The reed bed should be properly designed, constructed and maintained. The local SEPA office can supply a list of reed bed designers.

A reed bed system can be used as a secondary treatment for septic tank effluent. All reed beds require consent to discharge.

5.4. Consent requirements

Under the provisions of the Control of Pollution Act 1974 (as amended) a consent to discharge is required from SEPA for any discharge of sewage effluent into "Controlled waters". "Controlled waters" include all inland watercourses, coastal waters and groundwaters. A consent may also be required for any discharge into a soakaway or a self-contained pond. The holder of the discharge consent for a sewage treatment plant is responsible for ensuring that the plant is well maintained and that the effluent complies with the consent conditions. Such consents are not granted automatically and are not normally granted where a public foul sewer is available. There is an administration charge made by the Agency for application for consent and an annual fee too cover monitoring and other costs. **The administration fee currently stands at £79 inclusive of VAT for up to 4 houses.** The monitoring fee varies depending upon local circumstances. (See appended Control of Pollution Act 1974 (as amended for full details).

Other permissions may be required, for example the local authority building control department will usually require a building warrant for the installation. See appended Building Warrant and Planning Application forms)

5.5. Useful references

1. Code of Practice for the Design of Small Sewage Treatment Works and Cesspools. BS6297:1983: British Standards Institute.

2. Septic Tanks and Small Sewage Treatment Works, A Guide to Current Practice and Common Problems: 1993. Technical Note 146. Construction Industry Research and Information Association (CIRIA)

3. Septic tank systems: A users guide (CIRIA)

4. On site sewage disposal: Options (CIRIA)

5. Septic tank systems: Design and installation: CIRIA References 3-5 are available from your local SEPA office.

4. Policy and Practice for the Protection of Groundwater; ISBN 1-873160-37-2: The Stationery Office.

1. Groundwater Protection Strategy for Scotland, SEPA.

5.5.1. Guideline Per Capita Sewage Volumes

Property	Per Capita Volume (litres per day)	Property	Per Capita Volume (litres per day)
Domestic	180	Offices	55
Hotels	200	Factories	65
Restaurants	25	Public houses	15
Campsites	75	Caravans	120
Day schools	50	Rest homes	300
Boarding schools	180	Hospitals	450

Table 4. Per capita sewage volumes (http://www.environment-agency.gov.uk)

Note: Particular care is needed in designing treatment systems for catering establishments where significant quantities of grease and cooking oil may be present in the effluent. If these pass into treatment plants or soakaways, they may interfere with treatment and block drains and soakaways. It is recommended that expert advice is sought.

5.6. The Percolation Test

1. Avoid carrying out this test in extreme weather conditions such as drought, frost and heavy rain.
2. Excavate three holes 300mm square to a depth 250mm below the proposed invert level (bottom of pipe) of the land drain and space them evenly along the proposed line of the sub-surface irrigation system.

3. Fill each hole with water and allow to seep away overnight.

4. Next day, refill each hole with water to a depth of no more than 300mm and observe the time in seconds for the water to seep away completely.

5. Divide each figure by the depth of water in millimetres placed in the hole. This answer gives the time required (in seconds) for the water to drop 1mm.

6. This is the percolation value (in seconds). The average figure for the percolation value (V) is obtained by summing all three values and dividing by three.

7. If the percolation value exceeds 100sec/mm, then ground conditions may be unsuitable for discharge from a septic tank system and an alternative means of disposal will have to be considered that avoids ponding of septic effluent on the surface due to inefficient soakage.

8. For domestic premises, the floor area of soakaway land drains (A - in square metres) required may be calculated from:

$A = P \times V \times 0.25$ Where P is the number of persons served by the tank. V is the percolation value described above.

If in doubt, consult your professional adviser or Local Authority building control officer (Dornoch 01862 812008) for advice.

6. Recommendations

Twelve different sewage treatment systems were investigated in the course of this report. Of these, the most suitable for single domestic units and small clusters in the Duthchas project area are, in our opinion:

Add-on systems:

- Reed beds
- Peat systems
- W.E.T. systems

Replacement systems:

- Rotary biodiscs

We base our judgement upon the following factors:

2. Availability of systems and components
3. Ease and cost of maintenance
4. Potential for 'self-build'
5. Adaptability to various land conditions

Reed beds

Reed beds are eminently suitable for 'self-build' projects. It should be possible to construct a simple horizontal reed bed in an average plot of land for under £1,000. This figure assumes that the pipe run from property to reed bed is kept to a minimum and that no major civil engineering works are necessary on that plot.

Reed beds can be constructed on top of exposed bedrock if necessary. This would of course increase the initial building costs. Wherever a reed bed is sited there is an opportunity to landscape for wildlife. Reed beds can become thriving wildlife refuges, given a little thought and planning.

The choice of installation between a horizontal and vertical reed bed system depends upon the amount of fall available for the system. The vertical bed requires a fall of at least 1.5m (4¾ feet) whereas the horizontal reed bed requires virtually no fall. In the UK horizontal beds are by far the more popular option, being easily built and landscaped.

As a general rule of thumb the surface area of a horizontal reed bed should be $5m^2$ per person. The vertical bed area will depend upon the depth of media. The reed bed area required for a typical three-bedroom house is $30m^2$. The shape of a reed bed is entirely up to the individual. There is no restriction except that of space, providing that the correct surface area is available.

There are several examples of working reed beds in the local area. SEPA hold a list of Control Of Pollution Act (COPA) consents for these properties.

Peat systems
Peat systems require professional installation. This raises the initial cost of the system but once installed there is little maintenance required. These systems are readily available through an agent in Wick. In tests the Puraflo™ peat system manufacturer claims that all the parameters listed in Table 2 are consistently achievable. The system relies on a small electrical pump which can cope with a head of up to 5m (16¼ feet). This reliance on electricity may be a consideration in the more rural areas.

W.E.T. systems
W.E.T. systems can be self-built after the operator has had some instruction or experience of the system. It should be possible to construct a system suitable for a three-bedroom house for around £2,000. However, at least one system, costing around £5,000, would have to be professionally installed to give experience to potential self-builders. Living Water of Edinburgh have designed a Wetland system for a house in Skerray. This design is currently being considered by SEPA.

The system is by-and-large self-sustaining and requires little maintenance. Materials for construction should be available locally. The system may or may not require a butyl liner depending upon the porosity of the soil.

These systems have the advantage of providing habitat for wildlife, especially birds. They can be used as a feature in the garden and require slightly less space than the conventional horizontal reed bed.

The system relies on several different species of plants, some of which may not be suitable for the Duthchas area climate. According to the design consultants, Biologic Design Ltd., plants more suited to the climate could be substituted.

Rotary Biological Contactors (Biodiscs)
The rotary Biodisc system is requires some site preparation before delivery and is not a cheap option. However, once installed it claims to have the lowest running and maintenance cost of any packaged system currently available in its class. There are three standard drain invert options to match the site topography, minimising excavation depth. This system has the ability to smooth peak flows and spread the biological load throughout its working day. The system requires an electrical supply for the low wattage drive-motor.

The rotary Biodisc system is a complete replacement system requiring no septic tank.

6.1. North of Scotland Water Authority (NOSWA)
NOSWA have plans to introduce a sewage system to Skerray. However, this will not happen before the year 2008. NOSWA have indicated that if the Duthchas Project can connect 6 or more houses to a single settling tank and reed bed system, or other system suitable for connection to their proposed sewage treatment plant, then NOSWA *may* contribute a sum of money towards installation of that system. The total sum could be up to a maximum of £1,400 per household.

7. Some useful addresses

Environmental Research Institute
Castle Street
Thurso College
KW14 7XW

TEL: 01847 892474
FAX: 01847

SEPA North Office
Thurso Business Park
Thurso College KW14 7XW

TEL: 01847 894422
FAX: 01847 893365

Biologic Design Ltd.
Archenhills
Stanford Bishop
Bringsty
Worcestershire
WR6 5TZ

TEL/FAX: 01886 884721

Bord na Mona Environmental Division
Newbridge
Co. Kildare
Ireland

TEL: 00353 45 431201
FAX: 00353 45 431647

Centre For Alternative Technology
Panperthog
Machynlleth
Powys
SY20 9AZ

TEL: 01654 702400
FAX: 01654 702782
Email: consultancy@cat.org.uk
Internet: http://www.cat.org.uk

Klargester Environmental Ltd.
College Road
Aston Clinton
Aylesbury
Bucks

TEL: 01296 633000
FAX: 01296 633001
Internet: http://www.kingspanec.com

Johnston Smith Consulting Ltd.
The Old Manor
Sheepscombe
Near Stroud
Gloucestershire
GL6 7RH

TEL: 01452 814439
FAX: 01452 814358
Email: tedsmith@johnstonsmith.co.uk
Internet: http://www.johnstonsmith.co.uk

North of Scotland Water Authority
Morven House
Wick Industrial Estate
Wick
KW1 4QS

TEL: 0345 437437
FAX: 01955 603899

Roy Homes Ltd. (Puraflo advice)
8 Lotland Street
Longman Ind. Est.
Inverness
IV1 1PA

TEL: 01463 713838
FAX: 01463 713161
Email: roy@homes.prestel.co.uk
Internet: http://www.roy-homes.com

Living Water
5 Holyrood Road
Edinburgh
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8. Glossary of sewage terms

Activated Sludge process removes organic matter from sewage by saturating it with air and adding biologically active sludge.

Aeration Tank serves as a chamber for injecting air into water.

Algae are plants that grow in sunlit waters. They are a food for fish and small aquatic animals and, like all plants, put oxygen in the water.

Bacteria are small living organisms that often consume the organic constituents of sewage.

BOD, or biochemical oxygen demand, is the dissolved oxygen required by organisms for the aerobic decomposition of organic matter present in water. It is used as a measure in determining the efficiency of a sewage treatment plant.

Carbon removes organic matter from wastewater.

Chlorinator is a device for adding chlorine gas to sewage to kill infectious germs.

Coagulation is the clumping together of solids to make them settle out of the sewage faster. Coagulation of solids is brought about with the use of certain chemicals such as lime, alum and iron salts.

Combined Sewer carries both sewage and storm water run-off.

Comminutor is a device for the catching and shredding of heavy solid matter in the primary stage of waste treatment.

Diffused Air is a technique by which air under pressure is forced into sewage in an aeration tank. The air is pumped down into the sewage through a pipe and escapes out through holes in the side of the pipe.

Digestion of sludge takes place in tanks when the materials decompose, resulting in partial gasification, liquefaction, and mineralization of pollutants.

Distillation in waste treatment consists of heating the effluent and then removing the vapour or steam. When the steam is returned to a liquid it is almost pure water. The pollutants remain in the concentrated residue.

Effluent is the liquid that comes out of a treatment plant after completion of the treatment process.

Electrodialysis is a process that utilises direct current and an arrangement of permeable-active membranes to achieve separation of the soluble minerals from the water.

Floc is a clump of solids formed in sewage by biological or chemical action.

Flocculation is the process by which clumps of solids in sewage are made to increase in size by chemical, physical, or biological action. Fungi are small, non-chlorophyll-bearing plants that may play a useful role in trickling filter treatment operations.

Incineration consists of burning the sludge to remove the water and reduce the remaining residues to a safe, non-burnable ash. The ash can then be disposed of safely on land, in some waters, or underground locations depending upon national legislation.

Interceptor sewers in a combined system control the flow of the sewage to the treatment plant. In a storm, they allow some of the sewage to flow directly into a receiving stream. This protects the treatment plant from being overloaded in case of a sudden surge of water into the sewers. Interceptors are also used in separate sanitation systems to collect the flows from main and trunk sewers and carry them to the points of treatment.

Ion is an electrically charged atom or group of atoms that can be drawn from waste water during the electrodialysis process.

Lateral sewers are the pipes that run under the streets of a city and into which empty the sewers from homes or businesses.

Lagoons are ponds, usually man-made to rigid specifications, in which sunlight, algae, and oxygen interact to restore water to a reasonable state of purity.

Mechanical Aeration uses mechanical energy to inject air into water, causing the waste stream to absorb oxygen from the atmosphere.

Microbes are minute plant or animal life. Some microbes that may cause disease exist in sewage.

Mixed Liquor is a mixture of activated sludge and waters containing organic matter undergoing activated sludge treatment in the aeration tank.

Organic Matter is the carbonaceous waste contained in plant or animal matter and originating from domestic or industrial sources.

Oxidation is the addition of oxygen that breaks down organic wastes or chemicals in sewage by bacterial and chemical means.

Oxidation Pond is a man-made lake or body of water in which wastes are consumed by bacteria. It is used most frequently with other waste treatment processes. An oxidation pond is basically the same as a sewage lagoon.

Primary Treatment removes the material that floats or will settle in sewage. It is accomplished by using screens to catch the floating objects and tanks for the heavy matter to settle in.

Pollution results when animal, vegetable, mineral or heat waste or discharges reach water, making it less desirable for domestic, recreation, industry, or wildlife uses.

Polyelectrolytes are synthetic chemicals used to speed the removal of solids from sewage. The chemicals cause the solids to flocculate or clump together more rapidly than chemicals like alum or lime.

Receiving Waters are rivers, lakes, oceans, or other watercourses that receive treated or untreated waste waters.

Salts are the minerals that water picks up as it passes through the air, over and under the ground, and through household and industrial uses.

Sand Filters remove some suspended solids from sewage. Air and bacteria decompose additional wastes filtering through the sand. Cleaner water drains from the bed. The sludge accumulating at the surface must be removed from the bed periodically.

Sanitary Sewers, in a separate system, are pipes in a city that carry only domestic wastewater. The storm water runoff is taken care of by a separate system of pipes.

Secondary Treatment is the second step in most waste treatment systems in which bacteria consume the organic parts of the wastes. It is accomplished by bringing the sewage and bacteria together in trickling filters or in the activated sludge process.

Sedimentation Tanks helps remove solids from sewage. The wastewater is pumped to the tanks where the solids settle to the bottom or float on the top as scum. The scum is skimmed off the top, and solids on the bottom are pumped to incineration, digestion, filtration or other means of final disposal.

Septic Tanks are used for domestic wastes when a sewer line is not available to carry them to a treatment plant. The wastes are piped to underground tanks directly from the home or homes. The bacteria in the wastes decompose the organic waste and the sludge settles on the bottom of the tank. The effluent flows out of the tank into the ground through drains. The sludge is pumped out of the tanks, usually by commercial companies, at regular intervals.

Sewers are a system of pipes that collect and deliver wastewater to treatment plants or receiving streams.

Sludge is the solid matter that settles to the bottom, floats, or becomes suspended in the sedimentation tanks and must be disposed of by filtration and incineration or by transport to appropriate disposal sites.

Storm Sewers are a separate system of pipes that carry only runoffs from buildings and land during a storm.

Sterilization is the destruction of all living organisms. In contrast, disinfection is the destruction of most of the living organisms.

Suspended Solids are the small particles of solid pollutants which are present in sewage and which resist separation from the water by conventional means.

Trickling Filter is a support media for bacterial growth, usually a bed of rocks or stones. The sewage is trickled over the bed so the bacteria can break down the organic wastes. The bacteria collect on the stones through repeated use of the filter.

Waste Treatment Plant is a series of tanks, screens, filters, and other processes by which pollutants are removed from water.

Virus is the smallest form of micro-organism capable of causing disease.

9. Resources:

Publications

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Control of Pollution Act 1974 (as amended) Scheme of Annual Charges in Respect of Discharges to Controlled Waters and Land (Scotland). SEPA 1999
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Glossary supplied by: Aeration Industries International, Inc.
Reed bed photographs courtesy of Johnston Smith Consultants Ltd.
Wetland Photographs from http://www.usouthal.edu/
Other photographs Environmental Research Institute, Thurso.

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Living Water, Edinburgh
M.Miller, (builders), Wick

10. Appendix I – Enclosures.

(Commercial and other information)

1. Diagrams of a typical reed bed plus reed propagation instructions
2. Reed bed layout designed for 6 persons loading
3. Biologic Design Ltd. Wetland factsheets
4. Puraflo factsheets
5. Irish Agrément Board Building Certificate No.99/0060 – The Puraflo Peat System
6. Klargester Biodisc® factsheets
7. Excerpt from the "Control of Pollution Act 1974 (as amended)"
8. Living Water descriptive booklet
9. An Integrated Ecological Approach to On Site Water and Waste Management and Treatment. David and Jane Shields
10. Planning Application and Building Warrant forms and information. The Highland Council, Dornoch.