# Review of the application of shellfish by-products to land

August 2006

ADAS UK Ltd.

SR586

ISBN - 0 903941 49 X

**From Sea to plate, Seafish delivers expert knowledge, skills and support which help the UK Seafood Industry secure a sustainable and profitable future.**

ISBN - 0 903941 49 X

**Review of the application of shellfish by-products to agricultural land.**

| **Report prepared for :** | **Report prepared by:** |
| --- | --- |
| **The Seafish Industry Authority**<br>**Seafish House**<br>**St Andrew's Dock**<br>**Hull**<br>**HU3 4QE**<br>**Tel: 01482 327837** | **ADAS UK Ltd**<br>**Woodthorne**<br>**Wergs Road**<br>**Wolverhampton**<br>**WV6 8TW**<br>**Tel: 01902 754190** |

**Date: August 2006**

## Contents

## 1.0 Executive summary

A large amount of shellfish waste is produced each year in the UK for which there is no readily available recycling outlet. Application of the waste to agricultural land as an organic manure has been identified as the lowest cost disposal route available to the majority of the industry.

Since shellfish waste is generally classed as Category 3 under the Animal By-Products Regulations it has to undergo an approved treatment process before it may be spread to land. Provided certain standards are met, heat treatment, digestion by aerobic or anaerobic means and composting are acceptable pre-treatments for the waste. For a variety of reasons composting is likely to be the most practical treatment process for most shellfish processors.

An in-depth literature review of landspreading shellfish waste identified relatively few previous investigations which could contribute knowledge to the study.

The application of industrial wastes to land, including compost, is regulated throughout the EC by the Waste Framework Directive, which has as a primary objective the need to demonstrate benefit to agriculture from the landspreading activity. Using existing information from the literature, supported by recent laboratory analysis of four representative shellfish waste samples it can be easily demonstrated that shellfish waste contains valuable amounts of major crop nutrients, organic matter and, in some cases, lime. All these components are of potential benefit to agriculture.

Several persons with experience of composting shellfish waste were contacted and all willingly provided useful guidance on how to achieve success.

Livestock manures, sewage sludge and, more recently, green waste compost, have a successful track record of use in agriculture. Shellfish-based compost has similar characteristics. Examples are presented of how composted shellfish waste could be used on a grassland farm and an intensive arable farm. The benefit to agriculture is clearly demonstrated.

## 2.0 Introduction and purpose of the report

The purpose of this report is to investigate in detail the activity of applying shellfish waste by-products to agricultural land.

Towards the end of 2004 a survey was carried out by the Seafish Industry Authority (Seafish) to assess the amount of seafood waste produced by the UK industry and to seek information on its treatment, utilisation and disposal (Large 2005). During processing every effort is made to recover the maximum amount of edible products but the quantity of waste produced remains significant and from the survey is estimated to be around 312,875 tonnes per annum. Of this approximately 80% is finfish waste and 20% is derived from shellfish processing.

The survey also found that the majority of finfish processors have access to processing plants within reasonable distance for the production of fishmeal and other income generating products. Thus for most finfish processors the management of waste presents few problems. However, shellfish waste is unsuitable for conversion to fishmeal, because of low protein content and/or high shell content and the shellfish processors pay to dispose of the majority of the 63,000 tonnes of shellfish waste produced each year. At the time of the 2004 study the disposal cost to shellfish processors was estimated to be around £2.7 million per year.

Since the time the survey was undertaken landfill has largely been withdrawn as a permitted disposal route (some former foodstuffs, including cooked shellfish, may continue to be landfilled - see Section 3.3.2). There is increasing awareness of the limited availability of alternative waste management options currently available. It seems inevitable that, for the short to medium term at least, the costs of waste disposal to the shellfish industry will rise both because of the shortage of treatment sites and because waste will have to be transported further to the remaining suitable outlets.

A report by ADAS (ADAS, 2005, 1) investigated the options for disposal of seafood waste with particular emphasis on shellfish waste. The hierarchy of options was split into the three categories of recycling (most desirable), energy recovery and disposal (least desirable). Aspects such as availability of the technology, proven track record, suitability for seafish waste treatment, relative cost, restrictions imposed by legislation and environmental impact were considered. For a variety of reasons it was concluded that, for most of the industry, recycling the waste to land, after appropriate treatment, was likely to be the most practical and lowest cost option. The fact that shellfish waste is produced in widely dispersed areas of the UK (see Table 1) and that agricultural land is available locally to most for recycling were major factors.

It must be borne in mind that the Animal By-Products Regulations (ABPRs) prevent the direct spreading of untreated seafish waste, including cooked shellfish, to agricultural or any other land. Therefore in order to access the landspreading route the waste must undergo some approved treatment process, for example heat treatment (rendering), composting or digestion, in order to comply with the ABPRs for the elimination of pathogens and other animal disease agents. There are certain exceptions for using free-of-flesh shell for specific applications but these uses also require approval/licensing (see Section 8.1).

**Table 1. The quantity of shellfish waste produced and where**

| Area | Main types of shellfish waste produced | Total annual tonnage | Proportion of total UK shellfish waste production (%) |
|---|---|---|---|
| South West Scotland | *Nephrops* & Scallops | 11,500 | 18.3 |
| Eastern England | Cockles & Crustacea | 10,550 | 16.8 |
| Northern Ireland | *Nephrops* | 10,215 | 16.2 |
| Central Scotland | *Nephrops* | 10,000 | 15.9 |
| South West England | Crustacea | 8,385 | 13.3 |
| North East Scotland | *Nephrops* | 3,900 | 6.2 |
| Highlands & Islands | *Nephrops* & Scallops | 3,730 | 5.9 |
| North West England | Scallops & Whelks | 3,200 | 5.1 |
| North East England | Crustacea | 815 | 1.3 |
| Southern England | Crustacea | 380 | 0.6 |
| Humber Region | Crustacea | 250 | 0.4 |
| **Total** | | **62,925** | **100** |

Waste arisings are widely dispersed around the coastline of the UK with no particular region dominant but the largest quantities are produced in South West Scotland, Eastern England, Northern Ireland, Central Scotland and South West England. Although the average disposal cost per tonne varied somewhat between areas the typical cost was £40 to £45 per tonne of waste.

This report first considers the options available to the industry for the disposal of shellfish wastes, concluding that landspreading, after pre-treatment by composting, is the most appropriate. The concept of benefit to agriculture is discussed and, after presenting results of a literature review the means of demonstrating benefit to agriculture from seafish wastes is considered in detail. The legislation controlling landspreading is outlined. Information collected from discussions with the shellfish processing industry, compost researchers, farmers and the waste management industry on the use of composting to treat shellfish wastes is briefly presented. Finally, the operational level of landspreading is discussed with examples presented of the use of shellfish-based compost in agriculture. The sequence of the steps required to complete a landspreading operation is outlined in an appendix.

## 3.0 Options for disposal

### *3.1 The main requirements*

A preferred waste management treatment system must be practical in that it can be made readily available locally throughout the UK, is suitable for treating the wide range of shellfish waste products encountered and is cost effective. Ideally it should be available in the short to medium term and should result in a beneficial product. The ADAS (2005, 1) report reviewed the available legal options. The methodology included an evaluation of the process, level of technology required, complexity, scale of costs, whether marketable products are produced and a SWOT analysis. A best estimate of the time required establishing each facility was also made. Table 2 summarises the characteristics of the main treatment options.

**Table 2. Suitability of treatment options**

| | Permitting legislation | Relative cost of treatment | Relative capital cost | Relative recycling value | Relative size of installation | Build time | Practicality |
|---|---|---|---|---|---|---|---|
| Landspread after treatment | ABPR WMLR | x+(treatment xxx or xx) | x+(treatment xxx) | x | x | N/A | xxxx |
| Compost | ABPR | xx | xxx | x | xx | xx | xxx |
| Aerobic digestion | ABPR | xxx | xxx | x | x | xx | x |
| MBT | ABPR WMLR | xxx | xxx | x | xx | xx | xx |
| Autoclave | ABPR | xxxx | xx | x | x | x | xx |
| Anaerobic Digestion | ABPR | xx | xxx | xx | x | xx | xx |
| Incineration with energy | ABPR, WID | xxx | xx | x | xx | xxx | x |
| Biofuel production | Biofuels directive | xxxx | xxxx | xxxx | xxx | xxx | - |

x low, xx medium, xxx high , xxxx very high.
ABPR Animal By-Products Regulations
WMLR Waste Management Licensing Regulations or equivalent
WID Wastes Incineration Directive

The conclusion was that landspreading after pre-treatment of the waste is the most practical, cost-effective and suitable treatment which could be made readily available on a wide geographical basis across the UK within an acceptable timescale.

### *3.2 Influence of the Animal By-Products Regulations 2003 (ABPRs)*

The ABPRs were introduced into the UK in 2003 to enforce European legislation on the disposal of animal waste. They have a major impact on the disposal of seafood waste. The Regulations control the collection, transport, storage, handling, processing and use or disposal of animal by-products. Three categories of animal by-product are recognised, each with specific storage, handling and disposal requirements. The vast majority of waste from seafood processing is classed as Category 3, lowest risk material, for which the approved disposal routes are:

**Table 3. Permitted treatment/disposal for Category 3 waste**

| | |
|---|---|
| • Incineration<br>• Processing in an approved processing plant<br>• Rendering followed by incineration in approved plants<br>• Rendering followed by landfill<br>• Transformed into technical products at approved plants | • Used as a raw material in pet foods and animal feeds<br>• Transformed in a biogas or composting plant<br>• Ensiled or composted<br>• Where authorised, used as a feed for zoo, circus etc. |

It must be noted that despite the fact that cooked shellfish is suitable for human consumption it must not be spread to land without first undergoing an approved pre-treatment stage. It is insufficient to carry out a secondary cooking stage and processors should liase with their local State Veterinary Service for compliance standards.

### *3.3 Options which are no longer available*

#### *3.3.1 Disposal at sea*

The Food and Environment Protection Act 1985 controls the disposal of waste at sea through a strict licensing system. Most forms of disposal at sea were prohibited by the UK Government by the end of 1985. Once the catch has been landed, any waste from shore-based processing cannot be returned to the vessel or disposed of at sea without a licence. A licence must be sought from the environment regulator (sea) for the region in which the activity is to take place. A risk assessment which addresses the potential effect of the activity on the marine environment must be done along with an assessment of alternative means of disposal ashore. A substantial fee is payable to the regulator who duly makes the initial assumption that shore-based disposal is the preferred environmental option, as a consequence of which sea disposal is not a realistically available option for most wastes.

#### *3.3.2 Landfill*

Until the end of 2005 there was a temporary derogation under the ABPRs permitting the landfilling of former foodstuffs of animal origin, which included cooked shellfish and waste from the production of products which do not require cooking before they are eaten. Since the beginning of 2006 the direct landfilling of any form of raw or untreated seafood waste from processors is no longer permitted. Some former foodstuffs may continue to be landfilled. Thus certain cooked shellfish products may still go to landfill, including cooked prawns, dressed crabs and lobsters, seafood sticks and cooked, ready to eat mussels. Defra’s website on animal by-products and former foodstuffs may be consulted for further details.

### *3.4 Options that are available*

#### *3,4,1 Landspreading*

It must be emphasised at the outset that direct landspreading of shellfish waste is not permitted under the ABPRs, even for cooked shellfish. Although categorised as low risk (Category 3) the directive prohibits the landspreading of such wastes without a pre-treatment step. Category 3 waste may be treated by an approved process to convert it to, or incorporate it with, another product which itself may be spread to agricultural land. Permitted treatments include composting, digestion and rendering by heat treatment (see Table 3). Each of these treatments has minimum standards which are specified for particle size, temperature and time-retention.

Landspreading is controlled by individual country legislation throughout the UK (see Section 7.0). In England and Wales it is subject to The Waste Management Licensing Regulations 2005. There are a number of legislative issues to be addressed in each country of which the dominant requirement in all is to demonstrate potential benefit to agriculture. Therefore the first consideration of major importance for a seafish processor considering the landspreading route is to be able to demonstrate benefit to agriculture in the waste produced (see Section 4.0).

### *3.5 Pre-treatments suitable for landspreading*

#### *3.5.1 Composting*

The composting of fish waste is legally permitted by the ABPRs provided that it is treated at an approved composting plant. There are stringent requirements for the treatment of Category 3 wastes, which must meet the following process condition as well as prescriptive hygiene requirements: Enclosed reactor maintained at 70°C for 1 hour with a maximum particle size of 12 mm across one dimension.

Composting plants may only be built subject to obtaining the necessary planning permissions from the local council and a waste management licence from the regulator. Compliance with IPPC requirements and approval from the State Veterinary Service are mandatory for ABPR sites. These controls ensure that plants are only built in accordance with local needs, that wastes are managed to prevent harm to the environment and animal health is not put at risk.

The composting of fish waste is a commercial reality in North America and demonstration projects in the UK have proven its technical feasibility. The UK currently has at least 15 in-vessel sites that are approved to treat Category 3 animal by-products. In theory, the seafish industry could construct composting plants in the short to medium term to provide a local waste management system but high costs and the requirement for specialist expertise will be off-putting to most seafood businesses, who are more likely to prefer an external contractor to take their waste. Composting infrastructure is being built by the waste management industry in some areas and in the short term the industry could develop contracts with solution providers in the commercial waste management industry. Composting compares favourably with other treatment options. It has a proven track record and treating fish wastes is comparatively economic.

Throughout the remainder of this report composting is assumed to be the treatment process used in advance of landspreading because it could be made widely available across the UK and it is a well-understood technology. It also results directly in a product in solid form, which is more convenient for agricultural applications than the liquid primary end products from aerobic and anaerobic digestion treatment. Additionally, there is uncertainty about the ability of both aerobic digestion and anaerobic digestion to deal satisfactorily with much shell in shellfish wastes. Although heat treatment could result in an easily handled final product it is not expected to be widely adopted because of high energy consumption costs.

### *3.5.2 Aerobic digestion*
Aerobic digestion of food waste is regulated under the same regime as composting, hence the treatment time and temperature requirements are 70°C for 1 hour and particle size must be no more than 12 mm in one direction.

The technique employs bacteria to consume organic matter with the organic waste being degraded to water and carbon dioxide. The final metabolic waste products provide the bacteria with energy for growth and reproduction. For liquid phase aerobic treatment the waste material is macerated and mixed with water. The liquid containing macerated waste is transferred to reactor vessels fitted with oxygen distributors and stirring devices where thermophilic bacteria generate heat up to 75°C.

The high degree of automation adopted by this system and the ability to treat a single waste stream are advantages. Additionally the modular construction of the system means that it can be considered for stand-alone application at individual processor sites. The process is relatively simple but is dependent on reliability, accurate measurement and maintenance of oxygen supply.

Limited experience to date suggests the technique is suitable for treating flesh but unsuitable for thick shells. There is doubt about the process for dealing with soft shell such as *Nephrops* waste.

### *3.5.3 Anaerobic digestion*
For anaerobic digestion too the requirements under the ABPRs are a minimum temperature of 70°C for 1 hour and particle size must be no more than 12 mm in one direction.

Anaerobic bacterial digestion is long proven as a waste treatment process. It requires organic waste slurry to be fed into an enclosed vessel and maintained at a given temperature in the absence of oxygen for probably around 12 days for fish wastes. The process treats the waste for further recycling and recovers energy from the waste through the production of methane gas. The liquid digestate produced may be recycled to land as an organic manure.

The successful digesters of fish waste have only used finfish waste. It is more difficult to assess the suitability for shellfish digestion, as there are no current examples. The possibility of co-digestion of shellfish waste with other wastes in order to dilute the negative effects such as settlement of the shell may be an option. Anaerobic digestion is not considered an individual solution. It is only suitable on a regional basis requiring a large facility. These are best operated as generic waste management businesses. Therefore this solution will be reliant on the development of centralised anaerobic digesters.

Again, the technique is best suited to treating flesh and so far appears to be unsuitable for thick shells. Seafish is currently a partner in North East Scotland to assess the suitability of anaerobic digestion for treating soft shells.

#### *3.5.4 Heat treatment (rendering)*

Heat treatment is the long-established standard process used to produce fishmeal, for feeding to animals, from finfish. Similarly the treatment is approved as a precursor to landspreading waste subject to specific criteria on particle size, temperature and treatment retention time.

Although rendering can produce a suitable end product for recycling to land the high cost of heat treatment makes it most appropriate at large centralised facilities and hence potentially costly for the relatively modest quantities of shellfish waste produced at individual sites. However, small-scale operations might be economically feasible if access was readily available to existing steam production facilities. A simple secondary cooking stage for cooked shellfish would not be sufficient and processors wanting to know more should contact their local State Veterinary Service for guidance on ABPR compliance standards.

Since heat treatment is unlikely to be widely adopted by the seafish industry it is not considered further here.

## 4.0 What is meant by “Benefit to agriculture”?

Spreading waste onto agricultural land necessitates addressing the requirements of two third parties; the regulatory authority and the farmer. The farmer’s interests must always be taken into account because he has the final decision on the continuity of the recycling operation.

The legislation in each UK country which governs landspreading on agricultural land (see Section 7.0) has the overriding requirement that the activity must result in **benefit to agriculture**. The activity may not proceed without such proof being provided. Thus the first concern of a seafood processor intending to adopt this treatment option is to demonstrate potential agricultural benefit in the waste.

In recent years the agricultural industry has been in decline and suffered several setbacks resulting in severe financial pressure on most farm businesses. The cost of fertilisers, particularly nitrogen fertiliser, has risen sharply in the past two years. Typical inorganic fertiliser costs for winter wheat, potatoes and silage grass are £125, £215 and £200 per hectare respectively. Little wonder then that farmers are interested in obtaining low cost, preferably nil cost, crop nutrients and seafish wastes might be of sufficient potential benefit to provide a significant amount of the crop's need. Thus the farmer also requires proof of the benefit to him of allowing the waste to be spread on his land.

### *4.1 Soil fertility*

Soil fertility is a general term covering the complex interactions between pH (acidity), nutrient levels, organic matter content and the living organisms in the soil. The correct balance is necessary to achieve optimum crop yield and quality.

### *4.2 Soil pH*

Maintaining a satisfactory soil pH is basic to soil fertility. Lime is continually lost from soil at between 500 and 1,250 kg/ha every year. It is removed by crops, leached in drainage water and neutralised by the acidifying effect of nitrogen fertilisers. If this depletion goes unchecked the soil becomes slowly more acid to a point where crop yield and quality suffers. Either chalk or limestone (two forms of calcium carbonate) are used to control or prevent soil acidity. Since shellfish waste typically contains around 40 to 50% calcium carbonate it would automatically be an effective liming material on acid soils.

### *4.3 Nutrient supply*

Plants need adequate supplies of major nutrients such as nitrogen, phosphorus and potassium, of which nitrogen is the most important since it has the largest effect on crop yield and quality. Magnesium is a major secondary nutrient. Trace elements such as copper, zinc and manganese are also essential but in such small amounts that most soils can fully supply crop needs. Some essential nutrients are deposited from the atmosphere and in the past this has been a major source of sulphur. However, improvements in air quality over the past 20 years have made it increasingly necessary to add sulphur-containing fertilisers, particularly on sandy and shallow soils, across most of the UK and sulphur is an increasingly important applied nutrient.

Although the soil supplies an amount of all major nutrients it is necessary to supplement them by fertiliser or organic manure addition. To a crop it is immaterial as to whether its essential nutrients are supplied from a bag, the back end of a cow or a food waste. The characteristics of a waste which are of most interest to a farmer are its major crop nutrient content and hence its potential to substitute for purchased fertilisers.

### 4.4 Organic Matter

This is the most important single component of soils because organic matter:

- Stabilises soil structure, thereby increasing resistance to physical compaction and reducing risk of water and wind erosion;
- Improves nutrient content, particularly nitrogen, and its release to plants;
- Improves ease of cultivation, particularly on heavy soils;
- Markedly improves water-holding capacity of sandy soils;
- Encourages soil biological activity.

Levels of organic matter vary with soil type and farming system. Thus, on heavy soils under permanent grass in parts of Northern Ireland and Scotland they are typically 7 to 12% by weight whereas on light arable soils in Eastern England they may be as low as 1.2 to 2.5%.

Farmers are particularly interested in the major nutrient content of wastes, and the lime content too on certain soils, because they reflect an ongoing cost to the business. However, until 2005 most farmers paid little attention to soil organic matter content because its benefit is impossible to assess in financial terms.

Following revision of the Common Agricultural Policy (CAP) the Single Payment Scheme (SPS) has replaced most existing crop and livestock payments in the UK from 1 January 2005. The regulations differ slightly between England, Scotland, Wales and Northern Ireland but all require that farmers keep their land in Good Agricultural and Environmental Condition (GAEC). One of the key requirements for achieving GAEC is that farmers take positive action to maintain, and preferably increase, soil organic matter levels.

Regular addition of organic manures whether from farm animals or from industry such as food wastes, including seafish wastes, or sewage sludge will add nutrients as well as organic matter.

### 4.5 Biological Activity

Soils contain many living organisms, ranging from microscopic bacteria and fungi to burrowing animals of which earthworms are the most obvious. All play a part in maintaining the natural processes which are vital for maintaining the fertility of the soil. If soil pH, aeration (including drainage, where necessary) and particularly organic matter are managed carefully, the biological activity can function effectively and largely takes care of itself.

### 4.6 The influence of GAEC

Under EC legislation introduced in 2000 the Water Framework directive requires Member States to protect, enhance and restore surface and groundwater with the aim of achieving good chemical and ecological status by December 2015. A major cause of poor water quality is soil erosion which gradually transports nitrogen, phosphorus and agrochemicals into watercourses. These three soil components are the most damaging to aquatic life.

Reform of the common Agricultural Policy has resulted in decoupling of subsidies from the achievement of high crop yields and instead is now paid on a land area basis. This should help farmers realign their production to meet market and consumer requirements. Among compliance requirements, farmers must maintain their land in Good Agricultural and Environmental Condition, a chief aim of which is the effective control of soil erosion. Non-compliance by farmers with the GAEC requirements risks the financial penalty of a reduction in their land area subsidy.

The GAEC requirements are essentially similar in all UK countries but they are demonstrated in outline by the standards in England. These require that by 1 September 2006 farmers must have completed a simple risk-based Soil Protection Review. A template for completion is provided within the Cross Compliance Soil Protection Review document sent to all farmers in England at the beginning of 2006. Among other issues farmers must list the positive actions they intend to take to maintain soil organic matter on their land during 2007 since organic matter stabilises soil against erosion risk. It is already apparent that farmers are beginning to take more interest in the possibility of utilising bulky organic materials on their land and particular attention is focussing on the use of composted wastes. The organic matter content of seafish waste will become more attractive as a benefit when farmers, and regulators, inevitably recognise its importance.

Another requirement of the Soil Protection Review is that farmers are required to use the summary tables in a further document, Cross Compliance Guidance for Soil Management, which has also been supplied to farmers in England. Using the guidance farmers must consider the soil management measures they will apply in order to minimise the risk of soil erosion on a crop by crop and soil type basis across their farm during 2007. Particular attention must be paid to the higher risk of erosion which is normally present on sandy, silty, chalky and peaty soils, especially on sloping ground.

As well as erosion risk being influenced by soil type, nutrient levels also vary to an extent with soil type. Thus sandy soils are particularly prone to acidity and to deficiencies of potassium and magnesium. Conversely, crops growing on heavy soils are more likely to be affected by phosphorus deficiency. Peaty and chalky soils may be particularly low in potassium. Therefore seafood wastes which are rich in a particular nutrient may be especially attractive as replacements for fertiliser nutrients on different soil types.

## 5.0 Literature review

This survey covers all literature published on the application of shellfish to land either directly, after pre-treatment such as composting, or in extracted form. Despite a very wide ranging search the review discovered only a fairly small amount of usable/documented information relevant to the study and this is summarised below. Although there is more anecdotal information available, this has not been sufficient to include or draw firm conclusions from.

### *5.1 Background*

The processing of shellfish produces, on average, 50-60% solid waste, consisting mainly of exoskeleton material[1]. The waste consists of 25-40% protein, 15-25% chitin, and 40-50% calcium carbonate. Because of its relatively low protein content it is not regarded as a suitable source of animal feed. However, it is a candidate for use as a fertiliser consisting of approximately 6% N, 2% P and 1% K. It also contains much organic matter.

### *5.2 Direct application of shellfish waste to water*

Surface water acidification is currently a major problem affecting the ecology of streams and rivers in upland areas of Wales[2]. Remediation is normally carried out by the addition of limestone to neutralise the acidity. It has been found that cockle shells, either whole or crushed, and crushed whelk shells can raise alkalinity to buffer acid waters as least as effectively as limestone. Caution is necessary because of the presence of heavy metals and arsenic in the wastes. Crushed whelk shells typically have a relatively high flesh content which would result in an increase in the BOD of the treated water although techniques are available to fully remove flesh. Lobster, crab and shrimp shells have also been examined as a source of chitin for the cleaning up of wastewater[3].

### *5.3 Direct application of shellfish waste to land*

In theory shellfish waste could be considered as a potentially useful fertiliser for direct application to land. Although no longer permitted under the Animal By-Products Regulations direct landspreading has been investigated in the past.

Entire live shellfish, e.g. the slipper limpet (*Crepidula fornicata*) have been used as a source of fertiliser or as a means of neutralising soil acidity[4]. This organism, which can compete for space and food with commercial mollusc species such as scallops and oysters, has been harvested in considerable quantities. The limpets are taken to a factory where they are drained, taken through a rotary drier and then crushed to a powder. This process is carried out within 48 hours to minimise the effect of bacterial degradation of the flesh. Finished product is stored in silos and has the properties of a calcareous fertiliser. Processed crab waste has been used as a soil conditioner, mainly taking advantage of its liming value and as a slow release source of nitrogen[5].

Clandosan, a commercially available product of crustacean shells was found[6] to have potential as a nematicide against several plant parasitic nematodes. It was later found by the same investigator to have a potential as a slow-release nitrogen fertiliser[7].

A review in 2004[8] examined current activities involving the application of seafood waste to land. The review includes an analysis of mixed shellfish waste, Table 4.

**Table 4. Analysis of mixed shellfish waste**

| Determinant | Units (on dry matter basis) | Mixed shellfish waste |
|---|---|---|
| **PH** | | 7.4 |
| **Dry matter** | g/kg | 514 |
| **Total N** | g/kg | 26.6 |
| **Total P** | g/kg | 3.05 |
| **Total K** | g/kg | 1.79 |
| **Total Mg** | g/kg | 2.12 |
| **Loss on ignition*** | % wt/wt | 21.9 |
| **Organic carbon*** | % wt/wt | 10.5 |
| **C:N ratio** | | 4:1 |

* Two measures of organic matter content.

The report also provides analyses of individual shellfish waste types, both for major crop nutrients and heavy metals, Table 5.

**Table 5. Analysis of individual shellfish wastes**

| Determinant | Units (on dry matter basis) | Crab | Whelks | Mussels |
|---|---|---|---|---|
| **PH** | | 7.4 | 7.8 | 5.1 |
| **Dry matter** | g/kg | 579 | 778 | 607 |
| **Total N** | g/kg | 30.4 | 11.8 | 26.3 |
| **Ammonium N** | g/kg | 4.53 | 3.19 | 2.56 |
| **Total P** | g/kg | 1.6 | 1.07 | 0.91 |
| **Total K** | g/kg | 2.9 | 1.30 | 1.32 |
| **Total Mg** | g/kg | 7.4 | 1.08 | 0.81 |
| **Total lead** | mg/kg | <5.0 | <5.0 | <5.0 |
| **Total nickel** | mg/kg | <1.0 | <1.0 | <1.0 |
| **Total zinc** | mg/kg | 18.3 | 546 | 9.13 |
| **Total cadmium** | mg/kg | <0.10 | 4.44 | <0.10 |
| **Total chromium** | mg/kg | 1.51 | 1.74 | <0.20 |
| **Total copper** | mg/kg | 4.35 | 17.5 | 1.63 |
| **Organic carbon** | % wt/wt | 11.8 | 3.64 | 6.86 |
| **C:N ratio** | | 4:1 | 3:1 | 3:1 |

The large content of nitrogen relative to phosphorus and potassium in the waste is confirmed. Levels of heavy metals are generally very low, with even the much higher levels of zinc and cadmium in whelk waste being of little cause for concern.

The chemical composition and nutrient content of shrimp and crab processing discards are also given, Table 6.

**Table 6. Characteristics of shrimp and crab processing discards**

| Components | Composition | |
|---|---|---|
| | Shrimp | Crab |
| **Moisture content (%)** | 72.10 | 42.5 |
| **Crude protein (% dry wt)** | 44.12 | 19.08 |
| **Lipid (% dry wt)** | 8.39 | 0.85 |
| **Ash (% dry wt)** | 29.03 | 30.68 |
| **Chitin (% dry wt, deproteinised shells)** | 40.4 | 29.6 |
| **Carotenoids (ųg/g)** | 147.7 | 139.9 |
| **Flavorants (% of protein)** | 1.58 | 1.4 |

Details of the composition of cleaned and crushed scallops and crab shell are also provided. Table 7.

**Table 7. Composition of cleaned/crushed scallops and crab shell**

| Components (mg/kg unless otherwise stated) | Composition | |
|---|---|---|
| | Scallops | Crab |
| **Moisture content %** | 1.31 | 26.4 |
| **Calcium as Ca%** | 39.17 | 27.4 |
| **Calcium as $CaCO_3$** | 97.93 | 68.5 |
| **Copper** | 4.9 | 14.4 |
| **Lead** | 6.9 | 4.8 |
| **Zinc** | 54.3 | 52.7 |
| **Cadmium** | 1.87 | 0.58 |
| **Arsenic** | 11.8 | 14.4 |
| **Nickel** | 1.0 | 1.9 |
| **Chromium** | 38.5 | 26.9 |

A number of commercial products made from shellfish waste are available[9,10]. These are often used in horticulture or amateur gardening as a fertiliser, providing NPK (2.5:1.2:0.5% respectively) and Calcium 23%.

Mussel waste has been used on a small scale as a fertiliser in Sweden[11]. Trials were carried out by Hushnallingssallskapet in Uddevalla during 2002 and 2003 and showed that mussel waste works well as an agricultural fertiliser. Previous tests on the calcium in the shells showed a positive effect on application. A survey of farmers receiving the waste showed that they considered the material to be of interest but that odour was a problem unless the waste had been previously composted.

### *5.4 Composting shellfish waste*

A method of composting shrimp shells has been developed[12] with the objective of producing a high quality compost with a significant content of oligomeric chitin. Peat moss, sawdust and cow manure are first composted until the thermophilic stage is complete. 30% of shrimp waste, on a dry matter basis, is then added and a second thermophilic stage is carried out. The peak value for oligomeric chitin production was indicated by a decisive drop in ammonium content. The resultant compost has much higher levels of disease suppressive chitin than commercially available composts.

Cooked whelk waste has also been composted on a trial basis[13]. The whelk shell waste – consisting of crushed shells and remaining flesh – was first mixed with amendment (1 tonne of whelk waste to 1.8 tonnes of amendment) consisting of shredded green waste, spent grain, broiler litter and recycled compost. The whelk waste is classed as Category 3 under the Animal By-Products Regulations indicating that it can be composted to the EU standard at 70ºC for one hour, with a maximum particle size of 12 mm. Approximately 2.5m$^3$ of the mix was loaded into the silo-cage of the TEG composting system each day for 6 weeks. Although composting took place the required time temperature regime was not achieved. In a second trial, compost removed from the bottom of the silo was remixed with a 20% addition of fresh green waste and put back on to the top of the compost in the silo. This time all parts of the compost reached 70ºC for at least 36 hours.

On-farm composted scallop shells and green waste has been tested for bio-suppressiveness against the plant pathogen *Rhizoctonia solani* – the causative agent in damping off in radish[14]. Very positive growth results were obtained in pot trials using the scallop shell compost.

In the USA large scale composting of shell waste is undertaken. In one facility[15] 3,000 tonnes of clam waste, 1,000 tonnes of crab waste are composted annually with 5,000 tonnes of feathers and offal, 5,000 tonnes of poultry litter, and 4-5,000 tonnes of food residues. Roughly equal amounts of wood chip amendment are added. Another windrow composting facility[16] annually composts 2,000 tonnes of crab waste, 2,000 tonnes of chicken manure, 2,000 tonnes of food residuals, and 5,000 tonnes of clam waste, with roughly equal amounts of amendment for each feedstock. An in-vessel composting operation, using a rotating drum, and processing a mixture of seafood waste has been described[17]. In this process 52 tonnes of wood chips, 13 tonnes of seafood residues, 8 tonnes of food residuals and 4 tonnes of shredded paper are composted. The residence time in the drum is a minimum of 5 days.

A small-scale trial on the in-vessel composting of seafood waste, including mixed shellfish waste (crabs, *Nephrops*, mussels and whelks) has been carried out[18,19]. The shellfish was mixed with shredded green waste in the wet weight ratio of one part fish to 3 parts green waste. The composted product was held to be soil-like as defined by the BS3882 topsoil standard although the pH and stone (shell) content were ‘notable issues’. In terms of contamination, the levels of physical contaminants were within the thresholds of the PAS 100 standard except for the stone (shell) content. Bioassays revealed that the undiluted compost was not suitable as a growing medium simply because its nutrient content was so high that it damaged plants. However, in growing trials where the compost was added as a dressing to soil, tomato and barley plants showed improved germination and establishment along with subsequent improved growth and yield. The trial confirmed that composting can provide a safe and practical way of disposing of seafood by-products which would be of benefit to agriculture.

An economic analysis of composting crab processing waste has been carried out[20]. In Maine, in 1998, landfilling crab waste cost over $M1.5 a year. Economic models of three systems were prepared: Ag-Bag composting, windrow composting, and landfill. The equivalent-uniform-annual-costs were used to compare the three systems along with profit analysis. None of the models was found to be profitable at small throughputs, but windrow composting resulted in the smallest loss and became profitable when throughput exceeded 1,000 tonnes a year.

Crab and fish offal have been combined with wood shavings and sphagnum peat moss to produce a windrowed compost that is sold as an all purpose soil enhancer[21]. A report in 2003[22] describes compost being made from crab, lobster, shrimp and fish waste mixed with horse manure sawdust bedding as an amendment. The compost is then mixed with bark, peat and perlite and bagged. It is then sold as a tree and shrub planting compost. Alternatively, it is mixed with topsoil in order to produce a lawn dressing, or sold directly as a soil improver. It was found that the presence of shell in the compost improved its water holding capacity and structure. Mussel waste has been co-composted with salmon residuals to produce a horticultural compost, while clam shells have been composted with poultry litter and wood chips to produce a golf course dressing[23]. Zebra mussels have been composted by static pile composting and aerated static pile composting[24].

### *5.5 Uses of shellfish waste to produce chitin and chitosan*

After cellulose, chitin is the most abundant biopolymer. Chitin can be converted into chitosan. Both chitin and chitosan have a number of uses such as water treatment, odour control and as components of edible products. In 1993 estimated world wide recovery of chitin from the processing of marine wastes such as shellfish, was 37,000 tonnes[25]. By 2000 this had increased to 80,000 tonnes[26]. The chitin can be recovered by chemical, biochemical and biological methods. The chitinous waste material can be demineralised and deproteinised by a strong acid or base[27]. However, this method creates waste disposal problems. Alternatively, micro-organisms, or proteolytic enzymes have been used to produce chitin from shellfish waste[28]. Chitinase production can also be carried out by using shrimp shellfish waste as a substrate for the solid state cultivation of *Aspergillus* sp[29]. Shellfish waste has also been crushed and boiled to prepare shrimp and crab shell powder to act as a substrate for chitinolytic micro-organisms[30].

Shrimp and crab waste have been analysed to look for nutrient value as well as chitin content[31]. This waste was found to contain, on a dry basis, 17.0 to 32.2% chitin and from 3.4 to 14.7 mg/100 g of carotenoid pigments. The chitin extracts contained 6.29 to 6.42% nitrogen. The residual protein contents in chitin from shrimp and crab shells were 2.3 and 0.4% respectively. Crab shell waste can be used to produce chitosan to adsorb metal ions from electroplating wastewaters, to then elute the metals and reuse them in the electroplating process[32]. Lead has also been removed from aqueous solutions using crab shell waste[33].

### *5.6 Chitin and disease suppression*

The hypothesis that chitin produced from crab-shell waste can be used for root pathogen suppression[34,35] is now well established. There are many references in the literature on its effectiveness, of which the following are examples.

Chitosan, a polymer of beta -1,4-D-glucosamine derived from crab-sell chitin has been applied to tomato plants prior to inoculation with the root pathogen, *Fusarium oxysporum f. sp. Radicislycopersici,* either by leaf spraying or root coating[36]. Chitosan has also been applied as seed coating[37]. Pulverised crab-shell, in association with Hairy Vetch and urea has been used to suppress Fusarium Wilt in watermelons[38]. Chitin waste-based composts have also been used to suppress oomycete plant pathogens[39].

## 6.0 Demonstrating benefit to agriculture in seafish waste

### *6.1 Appropriate laboratory analysis*

Under the Waste Framework Directive requirements the landspreading of waste must result in benefit to agriculture. The three characteristics of seafish waste which are most likely to provide benefit are:

- Major nutrient content
- Lime content
- Organic matter content

The literature review has confirmed that shellfish waste contains useful amounts of major crop nutrients, lime and organic matter, all of which are of confirmed benefit to agriculture.

When assessing an application for landspreading regulators will require a statement of benefit and this will require proof in the form of laboratory analysis of the waste to be spread. In practice it is the final material to be landspread for which analysis is needed and this may be a compost or a digestate but as a first step seafish processors should obtain chemical analysis of untreated waste as a guide to potential agricultural benefit. Samples of the seafish waste should be submitted for the following analysis: *Dry matter, total nitrogen, ammonium-nitrogen, phosphorus, potassium, sulphur, magnesium, total neutralising value (for lime equivalent) and organic carbon content.*

It is widely recognised that the organic carbon content of a material multiplied by the factor 1.724 gives an average measure of its organic matter content since organic matter is complex but chiefly composed of carbon with other elements such as hydrogen, oxygen, nitrogen and sulphur within the molecules. Alternatively, loss on ignition gives a more crude measure of organic matter content. Although not considered essential in the past, the analysis of waste for organic matter is highly desirable. With the increasing importance of the need to maintain or increase organic matter levels in soil it is likely that wastes will routinely be analysed for organic carbon content in future.

Because lack of potential risk to soil and crops must also be demonstrated the regulator will normally require analysis of the end product of composting or digestion to be analysed for a range of potentially toxic elements. This can normally be demonstrated by determination of zinc, copper, nickel, lead, cadmium, chromium and mercury. The heavy metal content of shellfish waste is normally low or very low although there is evidence to suggest whelks and scallops may contain higher levels of zinc and cadmium than other shellfish.

### *6.2 Example results of laboratory analysis*

#### *6.2.1 2006 samples*

For the purposes of this study, four samples of shellfish waste, two from Scotland and two from England, were submitted for laboratory analysis to demonstrate typical crop nutrient contents. Results were as follows:

**Table 8. Laboratory analysis of shellfish waste samples, mid 2006**

| **Crop nutrient** | **Units (on dry matter basis)** | **Whelks** | ***Nephrops*** | **Crab** | **Scallops** |
|---|---|---|---|---|---|
| **Dry matter** | % wt/wt | 22.7 | 21.0 | 40.3 | 20.3 |
| **Total nitrogen** | g/kg | 99.6 | 71.1 | 46.3 | 82.9 |
| **Ammonium-N** | mg/kg | 2250 | 4220 | 1220 | 5800 |
| **Total phosphorus** | mg/kg | 5070 | 14600 | 7820 | 3920 |
| **Total potassium** | mg/kg | 10000 | 7790 | 2270 | 6430 |
| **Total sulphur** | Mg/kg | 18200 | 5310 | 3000 | 8610 |
| **Total magnesium** | mg/kg | 2610 | 5930 | 10100 | 3350 |
| **Organic matter*** | % wt/wt | 57.1 | 20.1 | 21.9 | 47.9 |
| **Neutralising value** | % wt/wt | 1.1 | 3.0 | 10.0 | 1.0 |

* Calculated from organic carbon x 1.724

In Table 9 the same results are expressed as kg of crop nutrient per tonne of fresh waste where the wastes are compared with other organic manures which have a history of use in agriculture. Results of analysis of a compost which included shellfish waste in the feedstock (Archer and Baldwin, 2004) are also included.

**Table 9. Major crop nutrients in the wastes compared with traditional organic manures (kg per tonne of fresh weight)**

| | Dry matter % | Total Nitrogen (N) | $NH_4$-N | Phosphate ($P_2O_5$) | Potash ($K_2O$) | Sulphur (as $SO_3$) | Magnesium (as MgO) |
|---|---|---|---|---|---|---|---|
| **Whelks waste** | 23 | 22.6 | 0.51 | 2.6 | 2.7 | 10.3 | 1.0 |
| ***Nephrops* waste** | 21 | 14.9 | 0.89 | 7.0 | 2.0 | 2.8 | 2.1 |
| **Crab waste** | 40 | 18.7 | 0.49 | 7.2 | 1.1 | 3.0 | 6.8 |
| **Scallops waste** | 20 | 16.8 | 1.18 | 1.8 | 1.6 | 4.4 | 1.1 |
| **Cattle manure** | 25 | 6.0 | 1.1 | 3.5 | 8.0 | 1.8 | 0.7 |
| **Sewage sludge cake** | 25 | 7.5 | 1.0 | 9.0 | Trace | 6.0 | 1.3 |
| **Green waste compost** | 65 | 7.0 | 0.2 | 2.8 | 5.3 | 3.5 | 3.8 |
| **Shellfish-based compost** | 65 | 10.0 | 0.5 | 4.1 | 4.2 | ND | ND |

ND = analysis not done

The most striking feature of the results is the large content of nitrogen in the neat shellfish waste relative to cattle manure, sewage sludge and green waste compost. Similarly, the single sample of shellfish–based compost contains much nitrogen but since this was produced from a feedstock containing only 1 tonne of shellfish waste to 3 tonnes of shredded green waste it should be readily possible to produce a compost with higher nitrogen content. It is interesting to note that the ratio of nitrogen, phosphate and potash in the shellfish-based compost is approximately 2:1:1, which closely matches the nutrient requirement of many crops, making it more attractive to farmers.

The much lower phosphate and potash content of shellfish waste relative to nitrogen identified in the literature review is confirmed but the shellfish-based compost has good contents of both because of the contribution from the green waste. The sulphur and magnesium contents of the neat waste are good and they would be valuable components of compost or digestate produced from shellfish waste

Since nitrogen is the most important crop nutrient it is pleasing to note that the nitrogen content is both large and reasonably uniform between the four wastes. The four are much more variable in content of other nutrients, which emphasises the importance of carrying out sufficient laboratory analysis of both the untreated waste and the final product.

The whelk waste and scallop waste had particularly large contents of beneficial organic matter because both samples unusually contained much flesh with relatively little associated shell. Whelk waste especially is normally comprised mostly of shell. However, there can be large site to site variations in shell content with shell usually being the dominant proportion in whelk and scallop waste, demonstrating the importance of checking the waste from individual sites.

The literature review confirmed the beneficial effect of lime in shellfish waste. On certain beaches, particularly in north Cornwall and the west coast of Scotland, the sand contains a high proportion of calcium carbonate in the form of shell fragments. Locally such sands are cheap and effective liming materials used in both arable and grassland production. Ground chalk and limestone, the traditional materials used to combat soil acidity have neutralising values of 50 to 52%. Good quality calcareous sand has a neutralising value of 30 to 40%. The neutralising values of the four shellfish wastes collected for this study varied from 1% to 10%, reflecting the amount of shell in the waste.

When chalk and limestone are required they are typically applied at around 5 to 10 tonnes/ha which supplies 250 to 500 neutralising units. The crab waste, which had a high shell content would supply 250 neutralising units if spread at 25 tonnes/ha. Thus the crab waste would be very effective at combating soil acidity in addition to supplying crop nutrients and organic matter. Most whelk and scallop wastes would also have a liming value. Conversely, on very sandy and peaty soils the addition of unnecessary lime can raise soil pH to a point where trace element uptake is impaired and this will be guarded against by the farmer. However, in the vast majority of situations the addition of lime to soils which are not acid is unimportant. The flesh of shellfish waste is normally acid but because of its low chemical buffering capacity this does not interfere with the composting process or with soil pH on application to land.

### *6.2.2 2003 samples*

In 2004 ADAS (Archer and Baldwin, 2004) reported on seafish composting trials. Results of laboratory analysis of the neat feedstock shellfish waste used in that study were as follows:

**Table 10. Laboratory analysis of shellfish waste samples, late 2003.**

| Crop nutrient | Units (on dry matter basis) | Whelks | Nephrops | Crab | Mussels |
|---|---|---|---|---|---|
| **Dry matter** | % | 78 | 27 | 53 | 54 |
| **Total nitrogen** | g/kg | 7.1 | 47.5 | 34.9 | 39.7 |
| **Ammonium-N** | mg/kg | 1900 | 8580 | 3960 | 1520 |
| **Total phosphorus** | mg/kg | 899 | 15800 | 11600 | 930 |
| **Total potassium** | mg/kg | 1750 | 4820 | 2010 | 1620 |
| **Total magnesium** | mg/kg | 1020 | 8120 | 13200 | 830 |
| **Organic matter*** | % wt/wt | 11 | 23 | 39 | 37 |

* Calculated from organic carbon x 1.724

The high dry matter, low nitrogen and low organic matter content of the whelk waste in this sample compared to that in Table 8 reflects the much higher shell content of the 2003 sample. Nevertheless, it still contains a significant amount of beneficial crop nutrients and will also have a large liming value. This variability between samples of a given type of shellfish waste emphasises the importance of individual processors seeking waste analysis since the variable content of shell and flesh can markedly affect the results.

The content of major crop nutrients in the *Nephrops*, crab and mussels wastes is very good. Additionally these three wastes are well supplied with organic matter. Results for *Nephrops* and crab waste are similar in the two years 2003 and 2006 with the particularly high magnesium content of crab waste being prominent.

#### *6.2.3 2005 samples*

In 2005 ADAS (ADAS, 2005, 2) produced a report for Dumfries and Galloway Scottish Enterprise and Seafish for which further waste samples were collected.

**Table 11. Laboratory analysis of shellfish waste samples, early 2005.**

| Crop nutrient | Units (on dry matter basis) | *Nephrops* whole shell | *Nephrops* crushed shell | Queen scallops flesh only | Queen scallops with shells |
|---|---|---|---|---|---|
| **Dry matter** | % | 34 | 38 | 9 | 77 |
| **Total nitrogen** | g/kg | 63.9 | 53.2 | 16 | 5.9 |
| **Total phosphorus** | mg/kg | 13100 | 12500 | 5050 | 1890 |
| **Total potassium** | mg/kg | 6680 | 5570 | 1610 | 2940 |
| **Total sulphur** | mg/kg | 3700 | 2970 | 9780 | 4620 |
| **Total magnesium** | mg/kg | 7650 | 7960 | 1550 | 3560 |
| **Loss on ignition*** | % wt/wt | 46 | 46 | 94 | 9 |

* Approximately indicates % organic matter content.

As expected the two *Nephrops* samples have similar and large nutrient contents regardless of how the shell was treated and results are similar to those in Tables 8 and 10. The scallop waste containing shell has a high dry matter content and low organic matter level. Conversely the scallops flesh has a very high organic matter content and a valuable amount of crop nutrients although its nitrogen content is surprisingly low compared with that in other shellfish waste.

### *6.3 Control of pests and diseases in crops*

In order to produce large yields of high quality crops the farmer must achieve a high standard of pest and disease control. In conventional agriculture this is done by targeting crops at specified growth stages with a precise programme of agrochemical applications. Only by doing this can he be certain of adequate control. There are many literature references to the use of chitin from seafish waste to achieve a degree of pest or disease control in a wide range of crops. However, complete control is rare and the extent of its effect is largely unpredictable. It may be that in some circumstances the control achieved would be sufficient for the farmer to reduce his rate of agrochemical application but there will always be uncertainty. In general, it is considered that this property of shellfish waste is best regarded as a potential bonus and it is not a major benefit to stress to either regulators or the farmer.

## 7.0 Regulations governing landspreading of wastes

### *7.1 The Waste Framework directive*

UK waste management regulations enact the requirements contained in the Waste Framework Directive (Council directive 75/442/EEC). Article 4 of the Directive states that:
*Member states shall take the necessary measures to ensure the waste is recovered or disposed of without endangering human health and without using processes or methods which could harm the environment, and in particular:*

- *Without risk to water, air, soil, plants and animals*
- *Without causing a nuisance through noise or odours*
- *Without adversely affecting the countryside or places of special interest*

Article 11 of the Directive states that:
*Establishments or undertakings that carry out* ***waste recovery*** *may be* ***exempted*** *from the permit requirements*

Annex 11B defines operations that may lead to recovery. This includes:
***Spreading on land resulting in benefit to agriculture or ecological improvement,*** *including composting and other biological transformation processes.*

UK countries have produced their own versions of the implementation of the Waste Framework Directive requirements, copies of which can be obtained from the relevant regulator as follows:
England and Wales:-
The Environment Agency
www.environment-agency.gov.uk/subjects/waste
Scotland:-
Scottish Environment Protection Agency
www.sepa.org.uk/guidance/index
Northern Ireland:-
Environment and Heritage Service
www.ehsni.gov.uk/environment

Although the detail of the interpretation of the Waste Framework Directive requirements varies slightly between different UK countries the restrictions imposed on landspreading are typified by the Waste Management Licensing Regulations 2005 which apply in England and Wales.

In England and Wales the regulations currently provide 46 exemptions from the requirement for a waste management licence, including:

- Compost derived from source-segregated biodegradable waste
- Liquor from aerobic treatment of source-segregated biodegradable waste
- Digestate from anaerobic treatment of source-segregated biodegradable waste

Exclusion from the exemption requirement is being sought in England and Wales during 2006 for composts that comply with the BSI PAS 100:2005 standard. In Scotland (Waste Management Licensing Regulations 1994, as amended (Scotland) 2003 and 2004) composts meeting the PAS 100 standard do not require an exemption from application to land since qualifying composts are regarded as a product, not a waste. Digestates do require an exemption in Scotland but this issue too is currently under review. Thus some of the differences in detail between countries are significant and must be checked out. The England and Wales regulations require that:

**-** The exemption must be registered with, and approved by, the Environment Agency before spreading starts.
**-** The maximum land area which may be applied for in a single application is 50 ha and an administration fee of £546 is payable at application.
**-** No more than 250 tonnes/ha of the waste may be spread in any 12 months but subject to an upper threshold of nitrogen in the waste when applied to land inside a Nitrate Vulnerable Zone. In practice, if the final material spread to land is in the form of compost containing seafish waste in the feedstock its nitrogen content is likely to limit spreading rate to around 15 to 30 t/ha.
**-** No more than 1250 tonnes of the material to be spread may be stored at the spreading site and it must be stored securely.
**-** Operators are required to provide a certificate completed by a person of appropriate technical expertise showing that the spreading activity will provide **benefit to agriculture**.
**-** Laboratory analysis of both the waste and the land where it will be spread must be included at registration of the exemption
**-** The Environment Agency has the power to refuse an application if it believes it will not be carried out in accordance with the general rules or if it believes the activity will cause harm to human health or the environment.
**-** The Environment Agency is required to inspect the exempt site at least once a year.
- The exemption must be renewed within 12 months with a further administration fee of £412 being payable on re-notification to the regulator.

## 8.0 Other relevant legislation

### *8.1 Animal By-Products Regulations 2003 (ABPRs)*

The ABPRs permit the land application of Category 3 animal by-products provided that they are treated to the standards stipulated in the Regulations. Permitted treatments include composting, digestion and heat treatment.

Additionally, the ABPRs require that for compost or digestate treated to ABPR standards and intended to be spread on land used for grazing or for producing livestock feed crops:

- Pigs must not be allowed access to or consume any feed grown on the land for a period of 2 months following application.
- Other farmed livestock must not be allowed access to or consume any feed grown on the land for a period of 3 weeks following application.

Furthermore, in the case of shellfish waste there is an exemption from treatment for mollusc and crustacean shells from which the flesh has been removed and their use is permitted in:

(i) the production of aggregates;
(ii) use in gardens;
(iii) the construction, maintenance or repair of footpaths;
(iv) use in draining land; or
(v) ornamental use.

Gravel is normally used as permeable fill above drains in agricultural land, usually extending from the top of the drainage pipe up to around 30 cm below the soil surface. It must be noted that whereas clean shell may be used as permeable fill above agricultural drains without undergoing an ABPR-compliant treatment it may not be spread to the surface of the land to confer benefit to agriculture without approved pre-treatment.

The operator of a composting plant or digester must keep records of animal by-products which are received on the premises, and records of the treatment process. For land on which ruminant animals, pigs or birds are kept, farmers are required to keep records of the date, quantity and description of compost or digestion residues brought onto the premises. Also details of the land to which it is applied and the date on which ruminants, pigs or poultry first have access to the land after application.

General guidance on the disposal of animal by-products, including former foodstuffs of animal origin, is available on the UK rules from:
www.defra.gov.uk/animalh/by-prods/pdf/ffguidance

Country-specific guidance is available as follows:

England. The rules were introduced in England and Wales by the Animal By-Products (England) Regulations 2003, superseded on 28 September 2005. For guidance refer to:
http://www.defra.gov.uk/animalh/animindx.htm.

Scotland. In Scotland, the regulations are covered by the Animal By-Products (Scotland) Regulations 2003 and details can be found at:
http://www.scotland.gov.uk/Topics/Agriculture/animal-welfare/policies/PolicyInfo/PICintroduction.

Northern Ireland. The Department of Agriculture and Rural Development makes its own arrangements with local authorities.

Wales. Information on the Animal By-Products (Wales) Regulations 2003 is available within the animal health and welfare section of:
http://www.countryside.wales.gov.uk

### *8.2 Nitrate vulnerable zones regulations*

Nitrate lost from agricultural land is the main source of nitrate in rivers and aquifers in Western Europe. High levels of nitrate in certain waters have given rise to environmental health concerns and these have been reflected in the EC Nitrates Directive (91/676/EC), which is aimed at reducing nitrate pollution from agriculture. The Directive required Nitrate Vulnerable Zones (NVZs) to be established in polluted catchments where nitrate from agricultural land is causing pollution of water sources and for Action Programme measures to be implemented in those zones to reduce nitrate pollution.

Polluted waters are defined in the Directive as:

- Surface fresh waters that contain or could contain, if preventative action is not taken, nitrate concentrations greater than 50 mg/l.
- Ground waters that contain or could contain, if preventative action is not taken, nitrate concentrations greater than 50 mg/l.
- Natural freshwater lakes, or other freshwater bodies, estuaries, coastal waters and marine waters which are eutrophic or may become so in the near future if protective action is not taken.

It should be noted that not all land falls within an NVZ and the rules do not apply on land outside an NVZ. The proportion of land which is governed by the NVZ Action Programme rules in each UK country is approximately as follows: England 55%, Northern Ireland 100%, Scotland 15% and Wales 3%.

Furthermore, the NVZ rules only apply to agricultural land. Therefore the spreading of compost including seafood waste in the feedstock which is spread to non-agricultural land, such as contaminated former industrial land or other land restoration projects is not subject to the NVZ rules. In practice this allows far higher rates of application of compost than on agricultural land since there is no nitrogen-limiting factor.

Whereas the NVZ rules are broadly very similar in each UK country there are differences in detail. Specific information for each country is available from the following sources:

England
www.defra.gov.uk/environment/water/quality/nitrate.

Scotland
http://www.scotland.gov.uk/Topics/Agriculture/Environment/NVZintro/NVZintr

Northern Ireland
http://www.ruralni.gov.uk/environment/countryside/environmental_legislation/water_protection.htm

Wales
http://www.countryside.wales.gov.uk

The main rule affecting the spreading of any type of organic manure, whether livestock manure, compost or digestate, is the requirement that the amount spread on a field must not apply more than 250 kg/ha of total nitrogen over a period of twelve months. Since compost including seafood waste may typically have a total nitrogen content of around 10 kg/ $m^3$ or more this restricts the application to approximately 25 tonnes per hectare in any twelve month period.

For some kinds of organic manures there are closed spreading periods on certain soil types (those most at risk of nitrate leaching) when the manure may not be spread but this rule does not apply to compost or digestate.

To reduce the risk of surface run-off the NVZ rules require that organic manures are not applied when the soil is:

- waterlogged; or
- flooded; or
- frozen hard; or
- snow covered.

Organic manures must not be applied on steeply sloping fields, within 10 metres of surface water which includes lakes, rivers, streams and ditches and within 50 metres of a spring, well or borehole that supplies water for human consumption, or is used in a farm dairy.

Records must be kept by the farmer of when, where and at what rate of application the compost or digestate was spread along with the details of the crop subsequently grown and the timing and amount of inorganic nitrogen fertiliser also applied.

The UK is currently under scrutiny by the EC over its implementation of the Nitrate Directive. The possible revisions may have important impacts on the amount of material which may continue to be spread and seasonal windows for organic material spreading on agricultural land may be more important in future. However, since the nitrogen in compost is available to crops only relatively slowly it is likely that compost spreading, whatever the feedstock, will be much less affected by possible changes than many livestock manures.

## 9.0 Brief guidance from practical experiences with composting

A number of waste management companies, farmers and research workers have included shellfish waste within the feedstock in past activities at composting sites. Several were contacted to seek information from first hand experience and their names are included in the list at Section 13. Although much of the activity to date has been obtained from composting systems which would not now be compliant with ABPR requirements, some useful guidance towards successful composting has been provided.

### *9.1 Particle size*.

Although the ABPRs require a maximum particle size of 12 mm for Category 3 material, this refers to the size in a single direction. Thus a large feather would be compliant since it is less than 12 mm thick in one plane. In early activity shell was commonly crushed to 10 mm fragments but three or four composters noted that if a significant amount of flesh is present there is a tendency for the material to “ball up”. Thus 10 to 20 mm shell fragments are now favoured to reduce compaction. Ease of obtaining suitable particle size varies with shellfish type: thus whelks with their thick, distorted walls are more difficult to cope with than the more open, thinner scallop shells.

### *9.2 Shell removal*.

Seafood waste is normally a combination of shell with flesh attached. The main benefit to agriculture derives from the nutrient content of the flesh since the liming potential of the shell is of value only on acid soils. Furthermore, shell is not degradable in a composting system and there is experience of shell separating out from the organic fraction of the compost. The consensus of opinion from composters is that as much shell as possible should be removed before sending shellfish waste for treatment.

### *9.3 Amendments*.

Shellfish waste is normally very dense and often wet. A major aim of composting is to enable air to permeate throughout the entire matrix of the waste. Therefore it is essential to open up the waste with a physical amendment. Additionally, achieving the right mix minimises odours which can be a serious problem with shellfish waste. Green waste containing a significant amount of woody material has been the most widely used bulking agent in the past. Mixtures of amendments have been used at most sites and have included straw, horse manure, grass cuttings, paper waste, poultry manure, wood waste and recycled compost. Where the shellfish waste consists mainly of flesh, green waste alone is suitable but where it is mostly shell the composting process is accelerated by the inclusion of a high-nitrogen substrate such as poultry manure. The possibility of including a reusable amendment, such as shredded tyres, which can be subsequently screened out, has been considered by some but is not known to have been used with seafood waste.

### *9.4 Waste to amendment ratio*.

The aim is to include as much seafood waste as possible within the mix, consistent with achieving an open matrix. Small-scale preliminary trials have been used by some to ascertain a suitable mix. The range of inclusion has varied in practice from 1 tonne of shellfish waste to 4 tonnes of amendment to 1 tonne of shellfish to only 1.5 tonnes of amendment. The ability to force air through the mix can permit a higher shellfish waste to amendment ratio but can also require more sophisticated odour control measures. It has been noted that the composition of green waste varies through the year from mainly woody material to one containing much fresh grass or leaf litter and this has to be borne in mind during feedstock preparation.

### *9.5 Product screening*.

After maturation, screening of compost is commonly done to 20 mm with the smaller fraction being suitable for landspreading. The oversize is usually recycled through the composting operation. Where green waste is used as an amendment it is important that it contains the minimum of physical contaminants, particularly plastic film and hard plastic since screening to 20 mm can result in a very visible amount of plastic being spread to land. The farmer-composters consulted maintain that farmers find the presence of plastic on their land visually offensive. The use of source-segregated garden and kitchen waste in the feedstock tends to be avoided because of the large amount of contamination which it sometimes contains. Shell fragments up to 20 mm are very noticeable if the shellfish waste contains mainly shell but on incorporation and subsequent cultivation it readily breaks down in the soil.

### *9.6 Mobile plant*.

Since seafish waste is often produced in relatively small quantity and usually remote from centralised composting facilities the possibility of using a mobile, ABPR-compliant, organic waste treatment plant has attractions. The licence holder would be able to manage a number of mobile units either as a local cluster where material from a number of waste producers is transported to the treatment plant, or individual units placed at the site of waste production.

### *9.7 Composting cost*.

Treatment systems to date have been largely experimental and small scale. Additionally, on-farm activities, although usually operated to a high standard and providing much valuable information, would commonly need expensive changes in management practices to become ABPR-compliant. Thus there is little helpful information about treatment costs from past composting experience with shellfish waste. However, one informed commentator reported recent gate fees of £50 to £65 per tonne for shellfish waste. Unless a small on-site plant or mobile composting unit is employed there could also be significant additional cost in transporting the waste to the treatment site, with £20 to £40 per tonne currently reported. As local composting plants are gradually commissioned these high costs will fall.

The most up-to-date information on composting technologies has been produced by The Composting Association (2004). This was collated from the system suppliers who are able to provide typical processing costs.

## 10.0 Landspreading scenarios

### *10.1 Sequence of events*

Landspreading is a specialist activity, which is successfully undertaken by a large number of waste management companies throughout the UK. A registered waste transporter must be employed to handle seafood waste and apply it to land. Whatever treatment system is used to produce a waste which is ABPR compliant, there are four basic steps in the subsequent landspreading operation which the waste transporter is responsible for and will arrange:

i) Preliminaries. Includes agricultural field site identification and assessment of its suitability, plus soil analysis, waste analysis and formal notification to the regulatory authority.

ii) Transport to field location, which may be remote from the site of treatment or waste production.

iii) Possible need for in-field storage although this is normally kept to a minimum. Provision for solid wastes is much more straightforward than the storage of liquids.

iv) Spreading. Solid wastes are normally applied to fields using rear discharge farmyard manure spreaders. Incorporation into the soil, by ploughing or discing, should be done as soon as possible after spreading to minimise odours. Liquid wastes are normally injected to minimise the risk of odour nuisance. There are a number of systems for injecting liquids into soil.

### *10.2 Site selection*.

The chosen site must allow easy access for the transport that delivers the waste. The site must also present a low risk to humans, animals and the environment, particularly water and air. Thus relatively flat fields with no adjacent watercourses that are remote from residential development are preferred. Waste contractors seek sandy and medium textured soils that are naturally free draining in order to avoid watercourses wherever possible.

Most wastes are produced throughout the year and, ideally, spreading would also take place throughout the year with the waste being taken from the production site and immediately spread to land. In practice crops cover the ground for most of the year in an arable rotation, preventing spreading until bare ground comes available. Since heavy soils tend to be cropped in the autumn, for example with winter cereals, the window available for spreading is limited to the period between harvest and sowing the next crop. Thus the three months between mid July and mid October is the main spreading period on heavy soil. Light textured soils commonly grow agricultural crops that are established in spring and since they are also better drained than heavy soils there can be an extended nine month long spreading opportunity between mid July and mid April.

Grassland can receive wastes throughout much of the year provided soil conditions are suitable to carry contractors' spreading machinery. Thus grassland on sandy soil in a low rainfall area can receive wastes throughout the winter. On grazed grass farmers are reluctant to receive waste from February to September because of the risk of livestock directly ingesting waste. On grass cut for hay or silage however, there is often an opportunity to spread to land in summer after taking a cut.

### *10.3 Cost of landspreading*

Since shellfish waste that contains much flesh is likely to produce a final material that is high in nitrogen, whether a digestate or a compost, it is likely that the total nitrogen content will be the limiting factor in restricting the waste application rate on agricultural land. Thus for compost an appropriate spreading rate might be around 20 tonnes/ha. It would be prudent to assume that suitable agricultural land might be somewhat distant from the site of waste treatment, leading to high transport costs. To undertake landspreading by carrying out the four steps described above the waste management industry opinion is that typical further costs, after composting treatment, would be between £15 and £20 per tonne.

Although compost can be financially very attractive to the farmer it must be realised that the farmer is also well aware that he is providing a service by solving a waste disposal problem. Because of this, most waste transporters spread compost to agricultural land at nil or very small cost to the farmer so little of the landspreading cost is normally recovered.

### *10.4 Restoration land*

Most organic waste that is landspread is applied to agricultural land since high transport costs dictate that the proximity of agricultural land throughout most of the UK is an advantage. However, where brownfield land, such as derelict industrial land and mineral extraction sites, including coalfield sites, is readily available locally for regeneration it may provide an opportunity to utilise seafish wastes in site restoration.

Since topsoil is usually in short supply at restoration sites the organic matter provided by wastes is often more attractive than their nutrient content because it can be combined with any native soil forming material such as subsoil, dredgings or coal shale to produce an artificial soil. Additionally, since the Nitrate Vulnerable Zone Regulations apply only to agricultural land the organic nitrogen content of wastes, which may be high in seafish-based wastes, is not a limiting factor on restoration land. Therefore far higher rates of application may be used to manufacture a soil on site than are permitted by legislation to be used in agriculture. Furthermore, on hostile sites such as acid coal shale the liming value of the shell in seafish wastes could be a major benefit.

WRAP (2006) investigated the potential use of compost to restore brownfield sites in the UK. By making contact with ongoing and proposed restoration activities a total of 67 sites covering 5,938 hectares have been positively identified where compost could provide a valuable soil-forming material. A range of planned end uses was studied including woodland, urban housing, amenity development and the production of biofuels such as willow, poplar and *Miscanthus* (elephant grass). Depending on the end use, the appropriate rate of compost application usually fell between 250 and 500 tonnes/ha. This has enabled the potential use for compost on restoration sites to be estimated at around 165,000 tonnes per year in 2007 and 2008.

**Table 12. Potential for use of compost on UK restoration sites**

| **Country** | **Number of sites** | **Hectares** | **Potential tonnes of compost use** | |
|---|---|---|---|---|
| | | | ***2007*** | ***2008*** |
| **Scotland** | 5 | 1740 | 34,280 | 34,280 |
| **Northern Ireland** | 5 | 345 | 6,630 | 6,630 |
| **Wales** | 5 | 239 | 1,490 | 1,740 |
| **England** | 52 | 3,614 | 121,260 | 122,410 |
| **Total** | ***67*** | ***5,938*** | ***163,660*** | ***165,060*** |

### *10.5 Compost, crops and soil types*

All crops require the same nutrients, albeit in varying quantities, and compost can supply a large amount of these essential nutrients. Thus silage grass may need 300 kg/ha of nitrogen, 75 kg/ha of phosphate and 250 kg/ha of potash in a year whereas spring barley may need only 150, 45, 35 and carrots 60, 100, 175 kg/ha respectively. Soil supplies much of the nutrient demand and fertiliser or organic manure is applied to support growth and to replace the nutrients removed by crops when they are harvested. Soils differ in their ability to supply nutrients: sandy soils tend to be poor suppliers of potash and clay soils are normally low in phosphate. The farmer uses soil analysis to check the ability of his land to supply crop nutrients and tops up with fertilisers or organic manures or a combination of the two.

Similarly laboratory analysis is used to calculate the input of nutrients from compost and other organic manures. Although compost will always contain nitrogen, phosphate and potash the farmer who receives compost can then use single nutrient inorganic fertilisers to compensate for any imbalance in nutrient supply due to compost use. Therefore, in practice despite the variation in crop need, the supply of nutrients from different soil types and compost nutrient content, the farmer can integrate the use of inorganic fertilisers with compost use to closely match nutrient inputs to the needs of his crops over a rotation, if not in a single year. In this way cost effective nutrient management is achieved. The end result is that, regardless of the feedstock detail, any compost containing shellfish waste can be used to advantage on a wide range of crops on all soil types throughout the UK. Where a compost contains an above average amount of a specific nutrient it may be especially welcome for a particular crop or soil type but it is no less beneficial in other cropping situations.

### *10.6 Disadvantages of using compost*

The perception by many farmers is that the chief disadvantage of using organic manures in general is their sheer bulk. Whereas a farmer may typically spread around 1 tonne/ha of inorganic fertiliser during the cropping season using a fertiliser spreader, compost (and other manures) is spread at around 15 to 30 tonnes/ha using larger, heavier tractors with loaders and muck spreaders. Thus there is a risk of causing soil structure damage, particularly on heavier soil types in a wet season. For this reason some farmers are reluctant to accept any type of organic manure on their land.

On very sandy or peaty soils the addition of an excessive amount of lime can immobilise trace elements in soil, resulting in trace element deficiency in crops. Farmers on such soils will be aware of the risk of adding too much shell on these soil types and will guard against it.

Farmers are very reluctant to accept compost containing noticeable amounts of physical contaminants such as glass, metal and plastic which makes selection of an uncontaminated amendment in the treatment process very important.

### *10.7 Putting it into practice*

Nutrient budgeting is an essential part of soil nutrient planning on agricultural land. The following two examples show how compost which includes shellfish in the feedstock can be used in conjunction with inorganic fertilisers. They show fields with three crops being grown in successive years and the nutrient budget over the three-year period.

The shellfish-based compost is assumed to have the nutrient content of that in the bottom line of Table 9, i.e. a dressing of 25 tonnes/ha will supply 250, 103 and 105 kg/ha of total nitrogen, phosphate and potash respectively. On land inside a Nitrate Vulnerable Zone 250 kg/ha is the maximum amount of total manure nitrogen that may be spread in any 12 month period. However, compost is a slow release organic manure and it is likely that only around 10 to 15% of the nitrogen will be available to the first crop grown after spreading. Some of the remaining nitrogen will contribute to soil fertility and will be released for crop uptake in later years.

### *10.7.1 Example 1*

A soil with soil analysis of phosphorus Index 2 and potassium Index 2-. Continuous grass rotation, being both cut for hay or silage and grazed by beef and sheep.

**Table 13. Grassland rotation**

| Crop | Nutrients required kg/ha<br>Nitrogen<br>N | <br>Phosphate<br>$P_2O_5$ | <br>Potash<br>$K_2O$ |
|---|---|---|---|
| **Year 1. 1 hay plus 3 grazings** | 220 | 50 | 90 |
| **Year 2. 2 silage cuts plus 2 grazings** | 300 | 65 | 170 |
| **Year 3. 4 grazings** | 210 | 20 | 0 |
| **Total required** | ***730*** | ***135*** | ***260*** |
| **Applied in year 1: 25 t/ha compost** | 30 | 103 | 105 |
| **Applied in year 2: 25 t/ha compost** | 30 | 103 | 105 |
| **Inorganic fertilisers required** | ***670*** | ***- 70*** | ***50*** |

An application of 25 t/ha in years 1 and 2 would provide most of the potash needed for three years and a surplus of phosphate which would slightly increase the soil phosphorus level or supply sufficient phosphate for the year 4 crop. This would provide major inorganic fertiliser cost savings for the farmer.

### *10.7.2 Example 2*

A soil with phosphorus Index 3 and potassium Index 2+ with higher value, more sensitive crops in the rotation.

**Table 14. Intensive arable rotation**

| | Nutrients required kg/ha | | |
|---|---|---|---|
| **Crop** | **Nitrogen N** | **Phosphate $P_2O_5$** | **Potash $K_2O$** |
| **Potatoes** | 200 | 130 | 275 |
| **Wheat** | 180 | 20 | 20 |
| **Onions** | 100 | 50 | 100 |
| **Total required** | ***480*** | ***200*** | ***395*** |
| **Applied in year 1: 25 t/ha compost** | 30 | 103 | 105 |
| **Applied in year 3: 25 t/ha compost** | 30 | 103 | 105 |
| **Inorganic fertilisers required** | ***420*** | ***0*** | ***185*** |

Compost spread at 25 t/ha in years 1 and 3, before the most demanding crops, would supply all the phosphate needed and halve the potash fertiliser requirement for the three years. In practice a small amount of additional inorganic phosphate fertiliser would be advisable for the potatoes since they are somewhat inefficient at taking up soil phosphorus.

The potential savings to the farmer on inorganic fertiliser costs approach £120 per hectare over the three year period for both of the above farming systems. In addition to the demonstrably large financial value there will be an unquantifiable benefit from the organic matter supplied. When spread on land which requires lime there is a further benefit. Thus compost containing shellfish waste is an attractive organic manure to the farmer.

## 11.0 Recommendations for future research

### *11.1 The composting activity*

Composting trials at a commercial scale should be carried out on single or mixed shellfish feedstock to determine efficiencies and costs of the process. Field scale trials of the resultant composts should also be pursued since this will provide the most persuasive information to farmers.

### *11.2 Nutrient release from compost*

#### *11.2.1 Nitrogen release*

Nitrogen is the most important nutrient to the farmer since it has the greatest effect on crop yield and quality. Additionally nitrogen is of major concern as a cause of water pollution. It is known that nitrogen is released very slowly from compost based entirely on green waste. Therefore it would be an advantage to better understand the release of nitrogen from compost containing shellfish waste in the feedstock, particularly in comparison with green waste compost since it is likely that shellfish-based compost will prove to be superior. Field trials on agricultural crops would be required to investigate this aspect.

#### *11.2.2 Sulphur release*

Sulphur is gaining importance as a nutrient which has to be supplied to crops as atmospheric levels of sulphur continue to decline. The release of sulphur from any type of compost has not been studied in the UK to date. It could be an important selling point if field research confirmed that shellfish waste used as a compost feedstock could readily satisfy the crop's need for sulphur. As with nitrogen release, sulphur availability studies would be best done in field research.

## 12.0 Conclusions

Approximately 63,000 tonnes of shellfish waste are produced in the UK each year. Since there is no large volume recycling market with a demand for shellfish waste a cost is associated with its disposal and as the number of disposal options reduces this cost is likely to rise. Composting to ABPR requirements followed by landspreading the shellfish-based compost has been identified as a waste disposal operation which is readily available to the majority of the industry at lowest cost.

Discussions with a number of individuals with experience of composting shellfish waste have highlighted several management practices which, when optimised, can successfully produce a compost using the waste as a feedstock component

Shellfish waste contains a large quantity of nitrogen and potentially valuable amounts of several other major crop nutrients. Additionally it contains much organic matter which is becoming increasingly regarded as a benefit in the farmer's perception with the emerging need to keep soil in Good Agricultural and Environmental Condition under the Single Farm Payment scheme. Furthermore, where the waste contains much shell it has a liming value which can be exploited in agriculture. Composted shellfish waste will retain these characteristics.

There is a long established tradition of using organic manures in agriculture. The realistic examples presented in this report of how composted shellfish waste could be used in contrasting crop rotations demonstrate how beneficial the wastes could be in reducing the farmer's inorganic fertiliser costs.

It is recommended that the composting of shellfish waste is developed and the release of nitrogen and sulphur from shellfish-based compost is studied

## 13.0 Persons consulted

During the course of gathering information for this study the following individuals in particular provided helpful comments, opinions or other assistance on either the composting of seafood waste or on landspreading. Their help, which was much appreciated, is acknowledged here with thanks.

Michaela Archer, Seafish Industry Authority, Hull.
Ben Ballantyne, The Snowie Group, Stirling.
M J Burgon, Burgon (Eyemouth) Ltd, Borders.
Paul Cartwright, Velcourt Ltd, Cambridge.
Alistair Cranston, farmer, Melrose, Borders.
S Evans, A M Seafoods, Lancashire.
J Gilliland, Excelar Resource, Ltrd, Bridlington, Yorkshire.
Andrew Groenhof, Eco Diagnostics Ltd, Newton Abbot, Devon.
R Haddock, farmer, Kingswear, Devon.
Alan Heyworth, TEG Environmental Plc, Preston.
Debbie Neely, ADAS, Lanarkshire.
P Olsen, SEPA, Stirling.
David Royle, Envar, Leeds.
M J Smith, Dawnfresh Seafoods, Lanarkshire.
Jonathan Whiteley, ADAS, Devon.

## 14.0 References

### *14.1 References outside the literature review*

ADAS 2005, (1). Seafood Waste Strategy. Consideration of treatment and disposal/utilisation options. Seafish Industry Authority.

ADAS 2005, (2). Dumfries and Galloway composting demonstration project: Phase 1 draft report. Seafish Industry Authority.

Archer, M and Baldwin, D, 2004. Composting seafood waste trials using replicated in-vessel composting units. Seafish library.

Large, M. 2005. Seafish Waste Survey. Seafish Industry Authority.

The Composting Association (2004). A Guide to In-Vessel Composting. Plus a directory of system suppliers.

WRAP (2006). Uses of compost in regeneration and remediation of brownfield sites in the UK.

### 14.2 Literature review references

[1] Chaney,D. (1991) Marine by-products as fertilisers, Components Newsletter, Winter, 1991, 2, (1).
[2] Edwards, P., Martins,B., (2004) AN assessment of the suitability of whelk and cockle shells as alternatives to limestone for ameliorating surface-water acidification., Tech. Memo. TMW04_12, National Laboratory Service, Llanelli, Wales.
[3] Anon (2000) Using seafood processing waste to clean up waste water, BioCycle, 41, 34
[4] Anon (2003) French turn slipper limpets into fertiliser, Shellfish News, No. 15, May 2003.
[5] Falen, C.L. (1998) Organic Fertilisers, University of Alaska, Crop Production and Management Series
[6] Spiegel, Y., Cohn,E., Chet, I., (1986) Use of chitin for controlling plant parasitic nematodes. 1. Direct effects on nematode reproduction and plant performance, Plant and Soil, 95, 87-95.
[7] Spiegel,Y., Kafkafi,U., Pressman,E, (1988) Evaluation of a protein-chitin derivative of crustacean shells as a slow-release nitrogen fertiliser on Chinese cabbage., J. Hort. Sci., 63, 621-627.
[8] Archer, M., (2004) The application of seafood products to land, Seafish Industry Authority
[9] http://www.goldinc.com/~thehunts/agrigulf.html
[10] http://www.dirtworksnet/crab+Kelp.html
[11] Olrog, L., Christensson,E., (2003) Musselodling och jorbruk I samverkan, Hushallnings Sallskapet
[12] Roy, S., Leclerc, P., Auger, F., Soucy, G., Moresoli, C., Cote, L., Potvin, D., Beaulieu, C., and Brzezinski, R., (1997) A novel two-phase composting process using shrimp shells as an amendment to partly composted biomass, Comp. Sci & Utiliz., 5, 52-64
[13] Heyworth, A., (2005) Composting trial for seafish, Sea Fish Industry Authority
[14] Eco Diagnostics Ltd. (2006) Investigating the plant growth benefits and disease suppressive properties of composts derived from seafood wastes, Report submitted to Seafish Industry Authority
[15] Block, D., (2000) Chitin Research opens up crab shell profits, BioCycle, 41, (12), 30-33.
[16] Block, D., (1997) Crab composter gets claws on new feedstocks, BioCycle, 38, 30-33
[17] Anon (2000) Seafood Gumbo in a composting vessel, BioCycle, 41, 71
[18] Anon (2005) Composting seafood, Sea Fish Industry Authority

[19] Baldwin, D.J., (2004) Trials Programme Sea Food Waste Treatment: Composting sea-food waste.
[20] Wentworth, D.S., Donahue, D.W., Seymour, R.M., (2002) Compost Sci. & Utiliz., 10, 47-56
[21] Gies, G., (1995) Composting food processing residuals, BioCycle, 36, 36-39
[22] Sherman, R., (2003) Markets for blends and bags of compost, BioCycle, 44, 45-49
[23] Anon (2004) Methods and economics of recycling seafood processing wastes, BioCycle, 45, 14-15.
[24] Anon (1992) Zebra mussels enter the composting pile, BioCycle, 33, 52
[25] Shaikh, S.A. and Deshpande, M.V. (1993) Chitinolytic enzymes: their contribution to basic and applied research., World J. Microbiol. Biotechnol., 9, 468-475.
[26] Patil, R.S., Ghormade, V., Deshpande, M.V. (2000) Chitinolytic enzymes: an exploration., Enzyme. Microbiol. Technol., 26, 473-483.
[27] Brine, C.J. and Austin, P.R., (1981) Chitin variability with species and method of preparation, Comp. Biochem. Physiol., 69B, 283-286.
[28] Gohel, V., Jiwan, D., Vyas, P., Chhatpar, H.S., (2005) Statistical optimization of chitinase production by Pantoea dispersa to enhance the degradation of crustacean chitin waste., J. Mibiobiol. Biotechnol., 15, 197-201.
[29] Rattanakit,N., Plikomol, A., Yano, S., Wakayama, M., Tachiki, T., (2002) Utilization of shrimp shellfish waste as a substrate for solid-state cultivation of Aspergillus sp. S1-13: Evaluation of a culture based on chitinase formation which is necessary for chitin-assimilation., J. Biosci. Bioeng., 93, 550-556.
[30] Wang, S.Y., MOyne,A>L., Thootappilly,G., Wu,S.J., Locy ,R.D., Singh,N.K., (2001). Purification and characterization of a *Bacillus cereu*s exochitinase., Enzyme Mibrob. Technol., 28, 492-498.
[31] Shahid, F., Synowiecki, J. (1991) Isolation and characterization of nutrients and value-added products from Snw Crab (Chinoecetes opilio) and shrimp (Pandalus borealis) processing discards.
[32] Coughlin, R.W., Deshaies, M.R., Davis, E.M., (1990) Chitosan in crab shell wastes purifies electroplating wastewater, Environ. Prog., 9, 35-39
[33] Kim, D.S., Park, B.Y., (2001) Effects on the removal of $Pb^{2+}$ from aqueous solutions by crab shell.
[34] Anon (1998) Using crabshell residues instead of methyl bromide to control pathogens, Biocycle, Novermber, 6.
[35] Anon (2000) Crabshell residues studied for soil pathogen control, Biocycle, June, 20
[36] Benhamou, N. and Theriault, G. (1992) Treatment with chitosan enhances resistance of tomato plants to the crown and root rot pathogen Fusarium oxysporum f. sp. Radicislycopersici, Physiol. Mol. Plant Pathol., 1, 33-52
[37] Benhamou, N., Lafontaine, P.J. and Nicole, M., (1994) Induction of systemic resistance to Fusarium crown and root in tomato plants by seed treatment with chitosan, Phytopathol., 84, 1432-1444.
[38] Zhou, X.G. and Everts, K.L., (2004) Suppression of Fusarium Wilt of watermelon by soil amendment with Hairy Vetch., Plant Dis., 88, 1357-1365.
[39] Labri, C., Leclerc, P., Cote,N., Roy, S., Brzezinski, R., Hogue, R., Beaulieu, C., (2001) Effect of chitin waste-based composts produced by two phase composting on two oomycete plant pathogens., Plant Soil, 235, 27-34.

# Appendix 1

### Key stages involved in landspreading wastes

The operation of an approved waste treatment system in compliance with ABPR requirements is a specialised and costly activity which would not normally be contemplated by a seafish processor. Consequently their waste treatment would almost without exception be contracted out to an existing waste management specialist. The waste contractor would have in place an effective and economical means of disposing of the treated product to land which involves completing the steps set out below. Thus in practice most seafish processors would employ a licensed contractor to undertake the entire process to both treat and dispose of their waste. However, an individual company or a local consortium producing a relatively large quantity of shellfish waste may be prepared to consider undertaking the entire activity.

The process for utilising free-of-flesh shell is virtually the same, with the exception of Stage 1.

1 Treat the waste to the full requirements of the Animal By-Products Regulations at a licensed site. This is not required for free-of-flesh shell.

2 Obtain chemical analysis at a laboratory of the final treated product to support a claim of agricultural benefit. Samples should be submitted for content of dry matter, total nitrogen, ammonium-nitrogen, phosphorus, potassium, sulphur, magnesium, total neutralising value (for lime equivalent), organic carbon content (for organic matter) and the seven heavy metals, zinc, copper, nickel, lead, cadmium, chromium and mercury.

3 Make contact with local farmers to discuss the benefits of the waste, which will be abundantly clear from the laboratory analysis. Ideally, have available the nutrient content of other organic manures such as cattle manure, sewage sludge cake and green waste compost as a comparison to emphasise the superior characteristics of the treated seafood-based waste. Heavy metal contents should be noted as suitably low.

4 Identify sites/fields which would be suitable to receive the waste. Obtain chemical analysis at a laboratory of each site/field topsoil to support a claim that the land requires crop nutrients and to confirm that the initial soil heavy metal levels are satisfactory. Samples should be submitted for content of pH, lime requirement, phosphorus, potassium, magnesium and the seven heavy metals, zinc, copper, nickel, lead, cadmium, chromium and mercury.

5 Obtain a brief written statement on the potential benefit to agriculture of the proposed landspreading. This statement must be provided by a

person with appropriate technical expertise who will typically be an agricultural consultant. The results of analysis of the treated waste and the field soils will form the basis of this assessment.

6 Contact the local environmental regulator to obtain application forms and written guidance to register the proposed activity.

7 Complete the application form. Submit the form to the regulator along with the laboratory analysis of the waste and the field soil plus location details of the spreading site including a site map. The expert's report confirming benefit to agriculture must be included along with any required payment to the regulator for dealing with the notification.

9 Await acceptance of the application from the regulator. It is an offence to carry out a landspreading activity before it is confirmed as accepted. Provided the application form is correctly filled out and all supporting documentation is in place approval can normally be counted on.

10 Engage the farmer or another registered waste management operator to transport and spread the waste at the notified site. The haulage may be done by the farmer on obtaining a waste haulage licence.

11 To continue the activity at the same farm in the following years a notification of renewal must be submitted annually.