

The development of a series of three purification tanks of standard design and their use with artificial seawater

Mise au point d'une série de trois bassins de purification de conception standard et leur utilisation avec de l'eau de mer artificielle

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Abstract

In England and Wales purification tanks are built to comply with broad operating criteria specified by the Ministry of Agriculture Fisheries and Food. These have been developed over many years with limited availability of data and has resulted in design restrictions which have limited the economic viability and effectiveness of the tanks. The approved method for the large scale purification of mussels has been to spread them in a single shallow layer in large outdoor tanks with access to a supply of clean sea water. This results in a purification plant that requires a lot of land, is labour intensive and generally remote from the harvesting area. In addition such tanks are exposed to ambient conditions and can result in filtration activity, upon which purification depends, being reduced or even prevented by wide fluctuations in water temperatures.

To overcome these problems Seafish have developed a modular tank design of 1500 kg capacity incorporating multi-layer stacking of mussels and the re-use of artificial sea water. This tank has a reduced land and labour requirement and enables a purification plant to be housed in a building, offering much improved control of environmental and hygiene conditions. The use of artificial sea water is not normally considered for large scale mussel purification, but with this development it is possible to extend its re-use over a period of one month. The purification plant can, therefore, be sited near to the mussel supply, reducing transport and handling costs and undesirable delay.

Following this successful development Seafish went on to develop two further modular designs for the small processor who may also wish to purify other bivalve molluscs such as oysters and clams. One incorporates the same multi-layer stacking design in a much smaller tank with a capacity of 750 kg of mussels. The other uses the concept of mounting boxes one above the other in a frame and cascading water down through them. In this system the boxes have been carefully designed to maintain uniform water flow and has a capacity of 2000 oysters. Both systems use artificial sea water.

The development of these modular tanks has enable Seafish to investigate and re-appraise the design and operating criteria for the purification of both mussels and oysters, but the work has not been limited to tank design alone. If molluscs are damaged or in physical stock then the effectiveness of purification and subsequent storage life may be significantly reduced. Trials with mussels have been carried out to develop new equipment to separate and sort at sea and also to make use of boxes, compatible with the purification tanks.

Résumé

En Angleterre et au Pays de Galles, les bassins de purification sont conçus en conformité avec des critères généraux d'exploitation stipulés par le ministère de l'Agriculture, de la Pêche et de l'Alimentation. Ces critères ont été mis en place depuis de nombreuses années

avec peu de données disponibles, ce qui a conduit à des restrictions sur la conception des bassins qui ont limité leur viabilité économique et leur efficacité. La méthode homologuée de purification des moules à grande échelle consiste à les étaler sur une seule couche dans des grands bassins extérieurs disposant d'un approvisionnement en eau de mer propre. Ceci aboutit à des installations de purification nécessitant un grand terrain, une main-d'œuvre intensive et généralement situés loin de la zone de récolte. En outre, de tels bassins sont exposés aux conditions du milieu, ce qui peut conduire à une diminution, voire à l'impossibilité des activités de filtration dont dépend la purification, en raison de fluctuations importantes de la température de l'eau.

Pour surmonter ces problèmes, Seafish a mis au point un bassin de conception modulaire d'une capacité de 1 500 kg, intégrant un empilage multicouche des moules et la réutilisation d'eau de mer artificielle. Ce bassin conduit à une réduction des besoins en terrain et en main-d'œuvre et permet d'abriter la station de purification dans un seul bâtiment, offrant ainsi une grande amélioration du contrôle environnemental et des conditions d'hygiène. L'utilisation d'eau de mer artificielle n'est généralement pas envisagée pour la purification à grande échelle de moules, mais grâce à ce développement, il est possible de prolonger sa réutilisation pendant un mois. La station de purification peut donc être implantée près des sites d'approvisionnement de moules, réduisant ainsi les frais de transport et de manutention et les délais indésirables.

Suite à ce succès, Seafish a ensuite mis au point deux autres conceptions modulaires destinées à des petits exploitants désireux de purifier d'autres mollusques bivalves, tels que les huîtres ou les palourdes. La première intègre le même système multicouches dans un bassin plus petit d'une capacité de 750 kg de moules. La deuxième fait appel à un concept qui consiste à empiler des caisses les unes sur les autres dans un bâti, puis à faire couler de l'eau en cascade à travers les caisses. Dans ce système, les caisses sont conçues de manière à maintenir un écoulement d'eau uniforme. Il a une capacité de 2 000 huîtres. Les deux systèmes utilisent de l'eau de mer artificielle.

Le développement de ces bassins modulaires a permis à Seafish d'étudier et de réévaluer les critères de conception et d'exploitation pour la purification des moules et des huîtres, mais les travaux ne se sont pas limités uniquement à la seule conception des bassins. En effet, si les mollusques sont endommagés ou en état de choc physique, l'efficacité de la purification et la durée de conservation peuvent être considérablement réduits. Des essais ont donc été réalisés sur des moules pour mettre au point de nouveaux matériels permettant de trier et de séparer les individus en mer et pour encourager l'utilisation de caisses compatibles avec les bassins de purification.

INTRODUCTION

In England and Wales plants used for the purification of bivalve molluscs must be licensed by the Department of Health following technical approval by the Ministry of Agriculture, Fisheries and Food. This can only be given if such plants are constructed to meet generalised design criteria specified by MAFF (West P.A., 1986) and can be shown to cleanse molluscs to a satisfactory standard.

Historically the sector of the Fishing Industry handling bivalve molluscs has been of low income with low levels of investment. It is consequently labour intensive with minimal facilities. The purification plant design criteria, developed over many years, reflected this and limited the economic viability and effectiveness of such plants.

Since 1986 Seafish has been investigating the handling and the purification of these shellfish with the objectives of increasing the quality and the safety of the products and the efficiency of the industry. Much basic research has led to sub-

stantial changes in the design criteria and to the development of three standard designs of large, medium and small-scale purification tanks suiting the needs of industry. These compact and efficient tanks provide controlled conditions for effective purification and have proven performance. This article concentrates on the development of those three standard designs rather than on the bulk of scientific work that led to their design. This work is continuing.

Seafish now provides an official recognised advisory service to industry and government on purification plant design and operation.

Initial trials with multi-layer stacking and re-use of artificial seawater

The approved method for the large scale purification of mussels has been to spread them out in a single 80mm deep layer in large concrete tanks with access to a supply of clean sea water (figure 1). This results in a purification plant that can require a lot of land and labour to operate, both of which are now expensive, and because of the water requirement the site is often remote from the port or harvesting area, adding transport cost and delay. Their size means that such tanks are inevitably outdoors and exposed to ambient temperature variations that can restrict or even prevent purification and allow contamination from birds and other animals. Originally mussels were spread out in bulk. Nowadays perforated containers are used but concern over high oxygen demands and the possibility of faecal material being re-ingested by mussels in lower layers has meant that the single layer approach had been retained. During each purification cycle the water is circulated once per hour through these tanks to ensure oxygen supply to the shellfish and to sterilise the water by UV light.

There is a need to place purification tanks under cover, ideally in a building, where environmental and hygiene conditions can more easily be controlled. Therefore, high density multi-layer designs were considered.

Seafish conducted a series of large scale trials in 1986/87 to investigate this (Jacklin M., P. Wilson, J.W. Denton, 1987) and found that 80mm layers of mussels stacked in boxes six deep (the limit of the tank used) would purify. It was essential that uniform water flow was maintained between layers to ensure adequate dissolved oxygen levels for all the shellfish. This was achieved by careful tank design including spray bar oxygenation and perforated flow control screens at both ends of the tank matched to the water flow.

The problem of access to a suitable sea water supply has often meant mussels being transported over long distances with subsequent delays, cost and repeated handling. Artificial sea water can be used but its use has been limited to a period of one week which would not normally be cost effective. Laboratory trials were therefore conducted in 1987/88 to investigate extended re-use (Wilson P., 1988 ; Wilson P. , 1989). An artificial sea water mix of five basic salts was used (Wood P.C., 1989) at a salinity of 27 parts per thousand. Two identical small purification tanks were constructed re-used water, and successive batches of mussels were purified over periods of one and two months. After each purification 90% of the re-used artificial sea water was retained with a 10% freshly made artificial sea water make up. The remaining 10% was drained to waste to ensure that sediment in the bottom of the tank could not be transferred

to the next batch. The trials proved successful provided the correct water quantity, flow and temperature conditions were maintained.

Development of the large scale mussel purification tank

Heiploeg Lynn, a shellfish processing company based at Kings Lynn in Norfolk, wished to expand their business to include mussel purification. Their existing site had the benefit of being adjacent to the quay where vessels landed their mussels, but was limited by lack of space to install tanks and no suitable clean sea water supply in the area. Purification tanks using multi-layer stacking and re-use of artificial sea water, with direct access to the mussel landing quay, appeared to be an ideal situation, but first trials had to be carried out combining the new concepts.

Local engineering company Bead Engineering, Heiploeg Lynn and Seafish decided to go ahead with a joint trial toward the end of 1988. Bead were to design, build and install a single tank to Seafish specification which would be installed at Heiploeg Lynn for trials by Seafish (Wilson P., 1989).

At the outset it was decided that the tank be of modular design with a nominal capacity of 1500kg of mussels. This would allow a size of tank that could be factory made and delivered on site complete, thereby making approval more straight forward as all such tanks would be the same. Several tanks of this capacity were also considered more effective than a single large tank as they could be used in sequence and give a more regular process flow, maximising labour and equipment utilisation. The tank was constructed in Type 316 Stainless Steel with external dimensions of 5.6m x 1.2m x 1.85m (figure 2) and installed in a

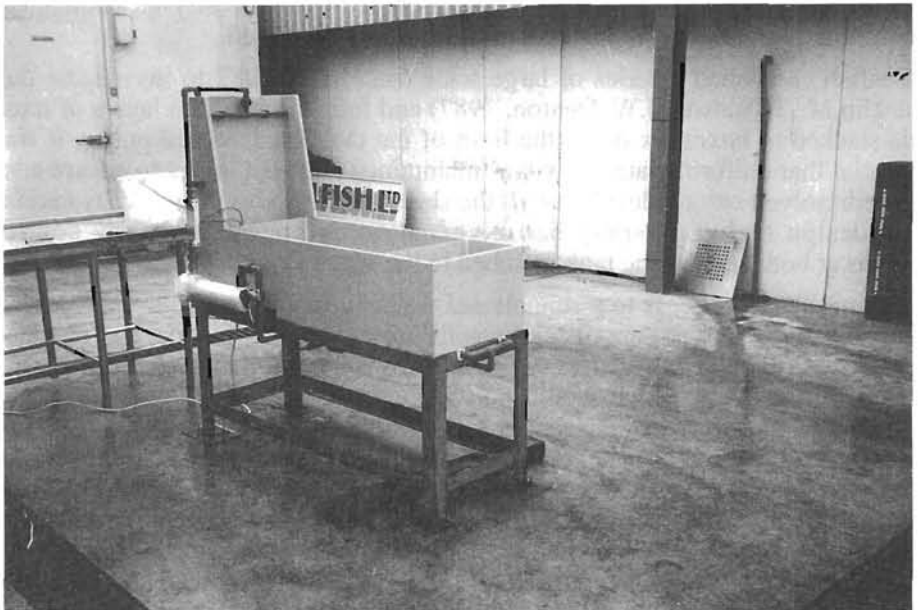


Figure 1: Small purification tank used in trials

small purpose built building for the trial. The tank held 96 boxes, each with 15kg of mussels, stacked six high on four pallets. Pump, UV steriliser and controls were attached to the back of the tank (figure 3), clear of any splashing and allowing free access for handling boxes.

In operation water cascades into one end of the tank, passes through a perforated flow screen, through the mass of shellfish, then through a further flow screen to the suction bar. Water is circulated via a UV steriliser at 9.2 m³/h, the equivalent to the water volume of the tank per hour and a water velocity through the shellfish of 6.0m/h. Because of the great mass of mussels it was not possible to maintain adequate dissolved oxygen levels at this low water flow rate and so the system was supplemented by installing a small rotary fan feeding an air diffuser mounted in the bottom of the tank beneath the water cascade.

The approach to the re-use of artificial sea water was based upon the earlier trials. A water/mussel ratio of 6 litres/kg with 10% make up of fresh artificial sea water after each purification was used. The purification tank pipework is interconnected to a separate stainless steel water reservoir which allows the purification tank to be filled or emptied via the circulation pump and U.V. steriliser. By draining down in this way the flow conditions are maintained which prevents the risk of re-contamination by sudden changes in water flow. The height of the suction pipe is fixed so that when draining down, suction is lost when 90% of the artificial sea water has been removed. The remaining 10% of artificial sea water together with sediment that has accumulated in the bottom of the tank is then flushed out to waste.

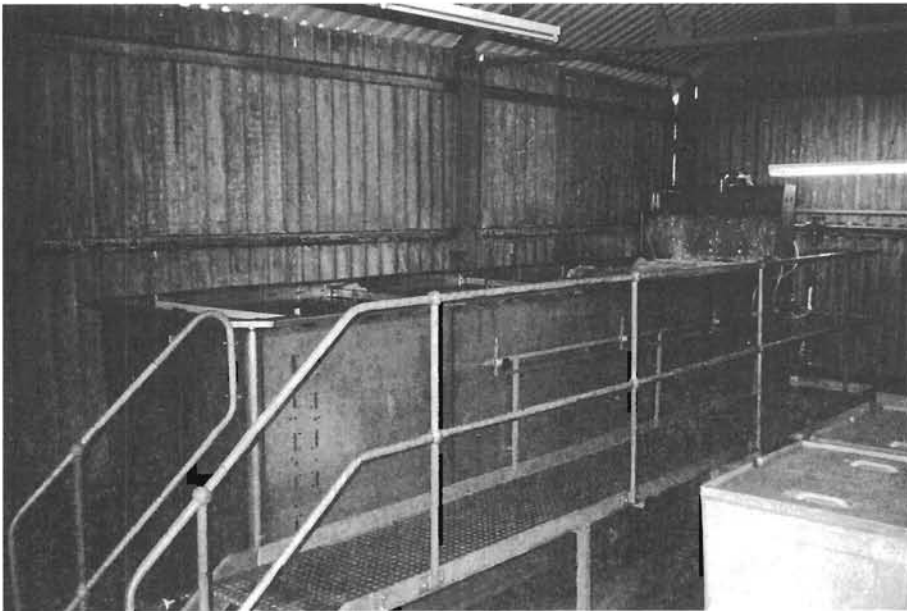


Figure 2: Large scale mussel purification tank on trial at Kings Lynn

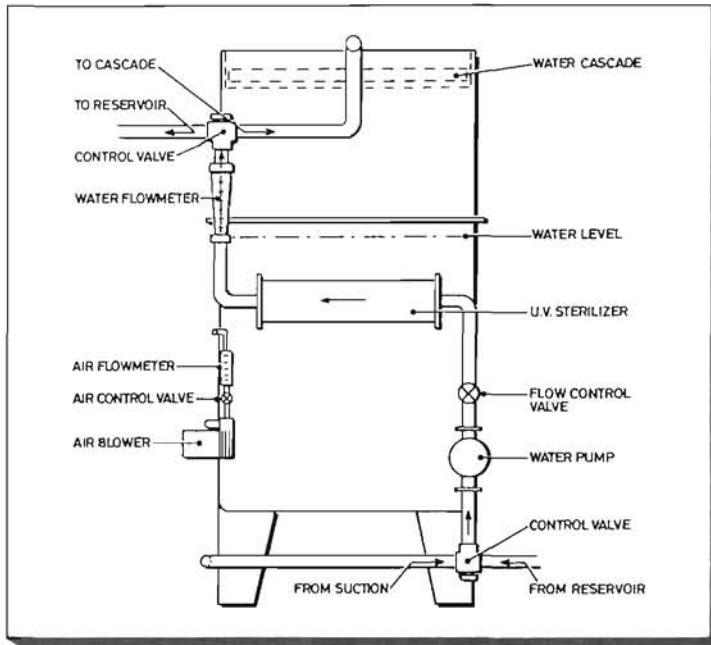


Figure 3: Controls mounted on rear of large scale purification tank



Figure 4: Purification plant at Kings Lynn

Trials were carried out in two stages with a single initial batch of artificial sea water. The tank was first operated for twelve consecutive purifications over a 3.5 week period and then intermittently over the next 6.5 weeks. During this second stage, combinations of box overloading and the use of unwashed mussels were investigated to establish possible effects of malpractice in tank operation. At all stages water quality was monitored in terms of salinity, temperature, dissolved oxygen, pH, ammonia and nitrate levels. In addition a small control tank was operated alongside the new tank with freshly made artificial sea water and mussels were held post-purification from both tanks to establish any adverse effects on subsequent mortality.

Overall the trials were very successful with sometimes very high *E.coli* levels in the mussels reducing to insignificant levels. Nevertheless this can only be achieved if the tank is operated within defined operating conditions. In particular the water temperature must be controlled. Below 5°C mussel activity was reduced, whereas above 12°C adequate dissolved oxygen levels could not be maintained, even with air diffusers, which created too much foam at high air flow rates. Subsequently the maximum operating temperature was extended to 15°C but only with partial loading of the tank. Artificial sea water, with 10% replacement at each use, was also successfully used over a ten week period with no apparent effect on purification or subsequent mortality.

Following the success of the trials, Heiploeg Lynn went on to install an eight tank plant of 42 tonnes per week capacity in 1989 (Wilson P., M. Boulter, 1990; Wilson P., 1988) which incorporated both mussel reception and packing areas, and an overhead crane for lifting pallets of boxes in and out of the tanks (figure 4). On the basis of the original trials the seven new tanks received approval without the need for individual bacteriological testing and consequently it was possible to operate the plant commercially at the start of the local mussel season in September 1989. This approval included the re-use of artificial sea water under specified conditions for a period of one month. The plant has continued to operate successfully.

Development of the medium scale purification tank

The purification tank developed at Kings Lynn is too large for many businesses. A scaled down version was considered but a smaller multi-layer tank of 750kg nominal capacity was already under development for mussel purification at Boston near to Kings Lynn. Seafish had been involved in its development with local fisherman David Coulson and processor Mick Butler, in early 1989, but there had been problems associated with the existing design criteria of circulating the tank water volume only once per hour, this being based on the traditional low density tanks using large volumes of sea water. With a water/mussel ratio of only 3.5/1, just over half that in the Kings Lynn tank it was not possible to maintain adequate dissolved oxygen levels in the water. Seafish decided to adopt a similar approach and develop this second modular tank of 750kg capacity whilst investigating the necessary water flow requirements.

The trials tank was made from a stiffened marine plywood lined with GRP, with internal dimensions of 2.44m x 1.2m x 1.2m. Water circulation was similar to that on the large tank with pump, U.V. steriliser and controls mounted at the

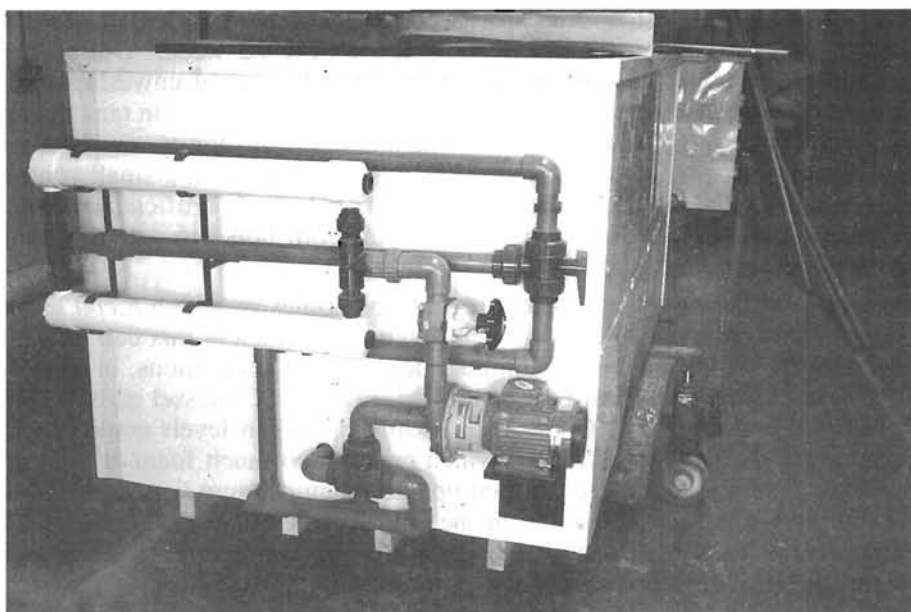


Figure 5: Controls mounted on rear of medium scale purification tank

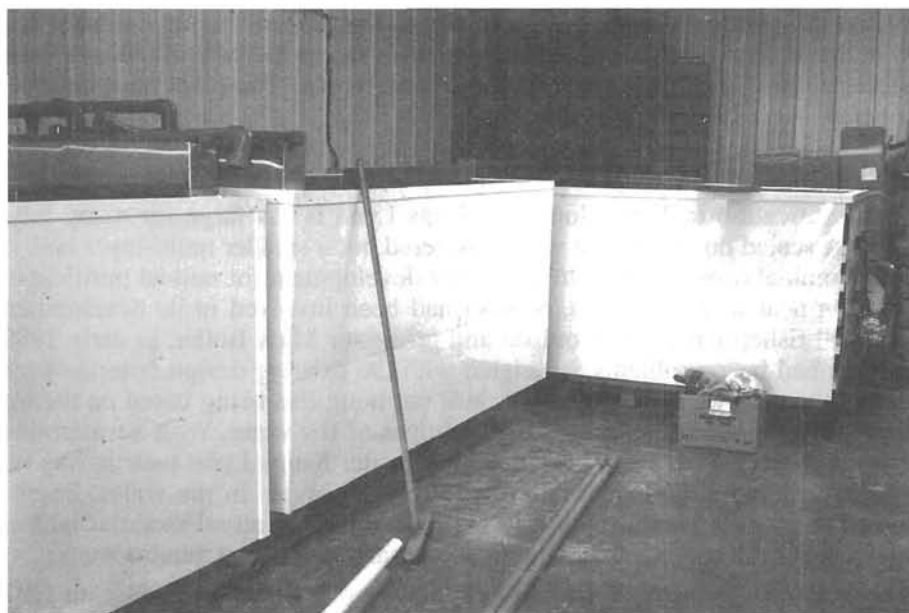


Figure 6: Medium scale purification tanks at Boston

back (figure 5) and flow screens separating boxes from water inlet and outlet. A spraybar was used instead of a cascade at the water inlet and no direct aeration was provided. A smaller but deeper mussel box was used. With the tanks' smaller capacity 50 of these boxes are loaded manually, five high, and sit clear of the tank bottom on raised battens moulded into the tank.

A series of trials were carried out at Mr Butler's premises over a ten week period, during December 1989-February 1990 (Boulter M., 1990), in which the combined effects of water flow rate, temperature and box loading were investigated. The trials were comprehensively monitored as before. It was found that with a tank load of 750kg (15kg per box) that a water flow of 8.5m³/h was required to maintain adequate dissolved oxygen levels at water temperatures of 5-10°C and 12.5m³/h at 10°-15°C. The higher flow at the equivalent of 5 tank changes per hour gave a water velocity through the shellfish of 12.5m/h, only twice that in the large tank with a single water change. Bacteriological testing showed that mussels were purifying under these conditions and hence that re-suspension and re-ingestion of detritus was not a problem at these flow velocities.

Because of the reduced water/mussel ratio of 3.5 litres/kg compared to 6.4 with the Kings Lynn tank, levels of ammonia in the re-used artificial sea water rose more rapidly and so its use was limited to a period of one week.

It is essential that water temperature is maintained within the specified levels. The high flow rates coupled with the insulative properties of the tank resulted in water temperatures rising by as much as 5°C above ambient. This was not a major problem during December-February but clearly could be a at other times. Therefore, a water cooling grid was fitted to the tank.

Following approval of the trials tank and two other identical units (figure 6) there has been much interest in them, not only in the U.K., but world-wide. As a result Mr Butler at Boston has simplified the tank construction to a GRP moulding and is currently providing tanks to processors in the U.K.

Development of the small scale vertical stack unit

An existing method of purification for small quantities of high value molluscs is to stack them in boxes supported one above the other in a vertical frame with sea water cascading down through them from one box to another. Seafish were concerned with the poor water flow characteristics of existing vertical stack units and the methods of draining down which did not minimise the chances of recontamination. Seafish decided to build a prototype unit to assist in trials investigating the purification of pacific oysters (*Crassostrea gigas*) and to develop a small-scale purification plant.

The prototype consisted of a painted wooden sump with single column of boxes mounted in a galvanised mild steel frame (figure 7). U.V. steriliser and controls were all mounted on a panel attached to one side and an in line water heater was included. The Allibert 12030 box already in common use was retained as it held a manageable load of 125 oysters and was of the right depth but the methods of water flow were changed. The problem was that of establishing a positive flow throughout each box from one end to the other without disturbance

of detritus. This was eventually achieved by attaching shaped stainless steel plates to each end of each box and staggering the boxes in the stack (figure 8). One plate directed the water flow out of the end of the box into the second plate in the box below. The second plate contained the water turbulence and directed the water flow. The problems of possible recontamination during draining down and removal from the stack were reduced by detail design and by placing oysters on a plastic grid within the box. Boxes drained individually, direct to the sump via two small holes sealed with bungs. These holes were positioned to retain 8% of the water in the box to prevent sediment from draining into the sump.

In October/December 1990 the prototype was installed at the premises of The Essex Oyster and Seafood Co Ltd at Maldon in Essex to investigate the re-use of artificial sea water with pacific oysters. Trials continued over 10.5 weeks and 15 purification cycles (Boulter M., J.W. Denton, 1991) with a water make up of 10% on each cycle. Dissolved oxygen levels, water temperature and quality and post purification mortality were all measured and bacteriological analysis of oys-



Figure 7: Prototype small scale vertical stack unit

ters carried out. Water flow was set at 900 litres/hr (1,5/h tank volumes) which gave a flow velocity of 11.5 m/h through the boxes, similar to that in the Medium scale tank. The reduced activity of oysters compared to mussels meant that dissolved oxygen levels remained high and no doubt accounted for there being no cumulative effects in water quality even though the water/oyster ratio was low at 3.7/1.

Essex Oyster and Seafood Company Ltd went ahead and built a unit to suit their own commercial needs, based upon the Seafish prototype. This was not intended as a standard design but it did take the development further. The sump now consisted of a standard plastic container of 650 litres capacity and supported 16 boxes in two columns to give a capacity of 2000 oysters. Boxes were now more conventionally drained through a plastic tap fitted to each box and directing water to the sump via a central drain pipe. A heater and thermostat had also been fitted in the sump. When approved this unit included the re-use of artificial sea water, under specified conditions, over a period of one month.

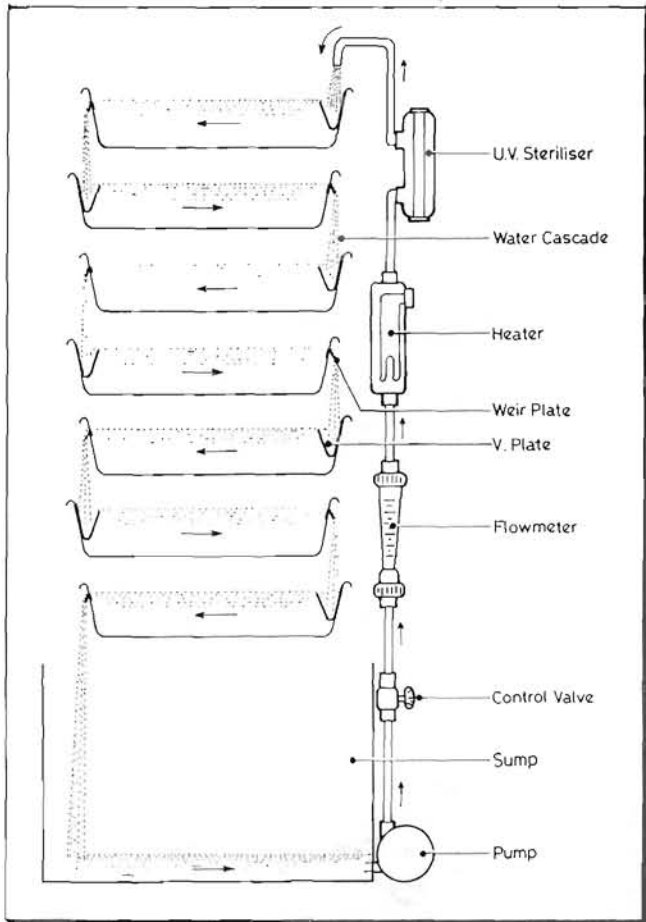


Figure 8: Water flow through prototype unit

A local aquarist wholesaler, C.J. Skilton, based in nearby Chelmsford, had assisted during the trials and with Seafish took the development to its final standard design stage, which is now commercially available (figure 9). This was not without its problems. The stainless steel plates attached to the boxes were expensive to make and install and so box manufacturers, Allibert U.K. Ltd, assisted in trials with various welded on plastic options. The one finally chosen is to weld plastic overflow pipes at one end of the box directing water into partitioned off sections of the box below. The galvanised frame was replaced with stainless steel and clad in plastic sheet to contain splashing and all plastic pipe-work and fittings are in ABS plastic.

Mollusc handling

Seafish development work to improve the effectiveness and efficiency of purification has not been limited to purification tanks alone. Molluscs that have been roughly handled or otherwise abused may die or remain inactive in the purifica-

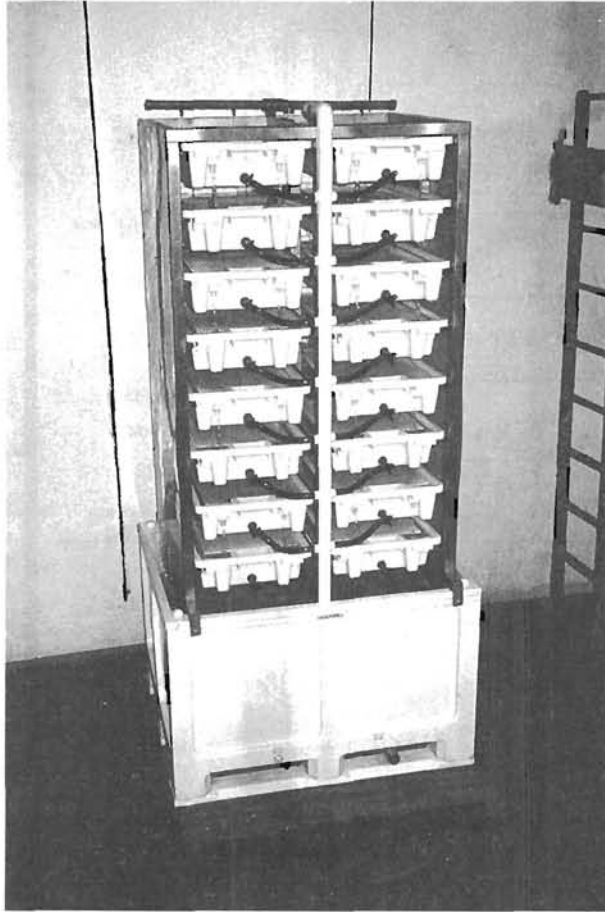


Figure 9: Commercial small scale vertical stack unit

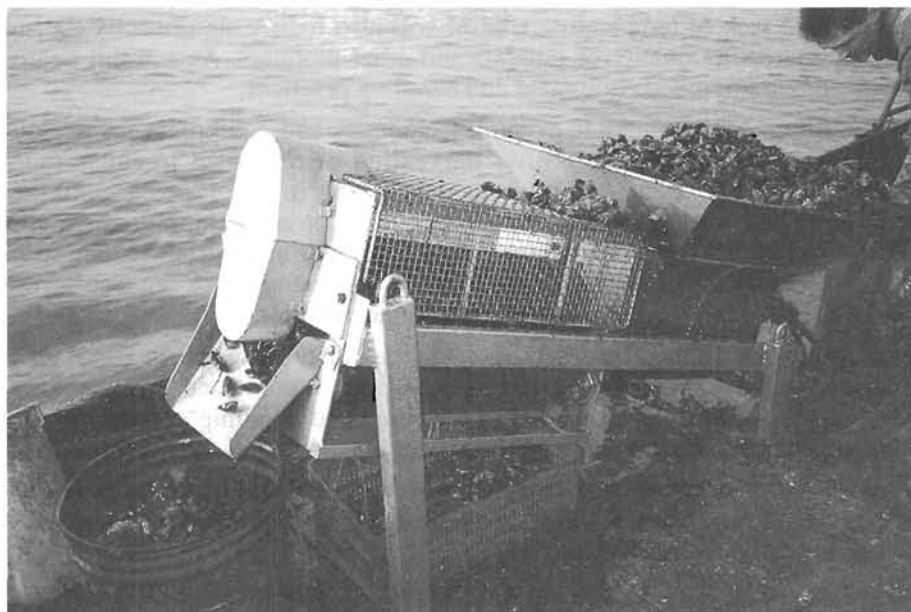


Figure 10: Combined declumping and sorting machine under development by Seafish



Figure 11: Trials with boxes instead of sacks with mussels

tion tank for many hours, regardless of the tank conditions. Investigation of mollusc handling by Seafish (Macnamara J., A. Pollack, 1988) has shown that rough handling and lack of temperature control will also reduce significantly the storage life and eating quality of mussels and other molluscs. As a result Seafish are developing improved equipment and handling practices.

With bottom grown mussels existing techniques and equipment for declumping and sorting immediately after harvesting were shown to cause much damage and shock. Seafish set about developing a new type of combined declumping and sorting machine based originally on a machine used for rope grown mussels. This machine (figure 10) is currently under trial but has so far proved to be successful not only in reducing damage and shock but also sorting more efficiently and requires less effort from the operator.

The rough handling of mussels in sacks has also been shown to result in damage and shock and so the use of boxes has been investigated (Macnamara J., 1988; Macnamara J., 1989), as part of an integrated handling system from the harvesting vessel direct to purification (figure 11).

Control of temperature and the avoidance of delay are essential. Contrary to popular belief Seafish has shown that direct icing of molluscs is beneficial when harvested in warm weather.

Further development

Our work on improvement to purification techniques and tank development continues.

Purification criteria for native oysters (*Ostrea edulis*) and clams are being investigated to ensure that the right conditions can be maintained if purified in the medium-scale tank and vertical stack units. The purification of cockles (*Cerastoderma edule*) has been investigated and the need shown for more stringent control of both handling and tank operating parameters than those required for other molluscs in the U.K.

The continuing requirement to purify mussels in a layer no more than 80mm deep (West P.A., 1986) necessitates a high level of manual effort and handling, particularly when dealing with large quantities as with the Seafish large scale tank. Trials will investigate the use of alternative techniques with mussels loaded in deep layers in suitable pallet boxes.

REFERENCES

- Boulter M., 1990. Mussel Purification, development of a medium-scale, deep stack purification tank. *Seafish Report*, **387**.
- Boulter M., J.W. Denton, 1991. Repeated re-use of artificial seawater in a small-scale vertical stack oyster purification plant under development by Seafish. *Seafish Report*.
- Jacklin M., P. Wilson, J.W. Denton, 1987. Mussel Purification - Commercial scale trial of multi-layered purification. *Seafish Technical Report*, **312**

- Macnamara J., 1988. Preliminary trials of a containerised mussel handling system. *Seafish Internal Report*, **1359**.
- Macnamara J., 1989. Further development of an integrated boxing system for mussels. *Seafish Internal Report*.
- Macnamara J., A. Pollack, 1988. Mussels. Improving quality through better storage, handling and temperature practices. *Seafish Report*, **352**.
- West P.A., 1986. Hazard Analysis Critical Control Point (HACCP) concept: application to bivalve shellfish purification systems. *Journal of Royal Society of Health*, **4**.
- Wilson P., 1988. Mussel Purification - Repeated re-use of artificial seawater in the purification process. *Seafish Technical Report*, **339**.
- Wilson P., 1989. Commercial Trial of a multi-layer mussel purification tank with re-use of artificial seawater. *Seafish Report*, **355**.
- Wilson P., 1989. Mussel Purification - Repeated re-use of artificial seawater in the purification process - Second series of laboratory scale trials. *Seafish Internal Report*, **1359**.
- Wilson P., M. Boulter, 1990. Design and Commission of a mussel purification plant at Kings Lynn. *Seafish Report*, **380**.
- Wood P.C., P.A. Ayres, 1977. Artificial Seawater for Shellfish Tanks. *Lab. Leaflet MAFF Directorate of Fishery Research*, Lowestoft, **39**.