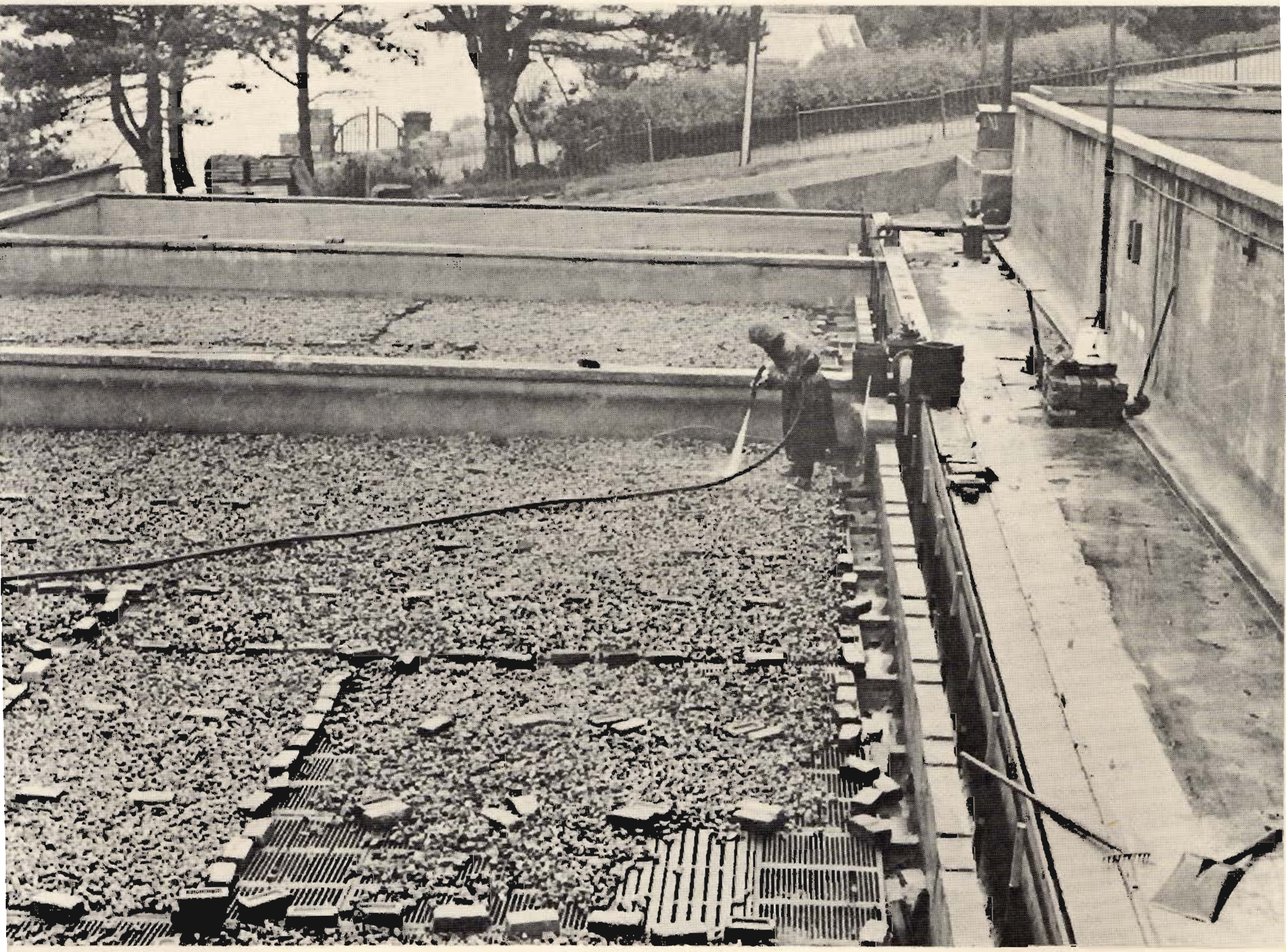
MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

THE PRODUCTION OF CLEAN SHELLFISH



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INTRODUCTION

The discharge of sewage into the sea can cause considerable damage to commercial shellfisheries, particularly those established in the littoral and sub-littoral zones of estuaries. Of the important commercial species, the filter-feeding cockle (Cardium edule), the edible mussel (Mytilus edulis), the European flat oyster (Ostrea edulis) and the Portuguese oyster (Crassostrea angulata) are the ones usually affected, these species being tolerant of the low salinities and exposure which characterize the estuarine environment. The damage caused by sewage effluents may be biological as a result of the interruption of the natural cycles of growth and reproduction; such damage is normally found adjacent to the outfall of poorly-treated domestic effluents, but is generally more widespread where the discharge also contains industrial effluents. Apart from damage which may be attributed to the chemical and physical characteristics of the effluent, considerable marketing difficulties may result from the contamination of shellfish by sewage bacteria which render the fish unsuitable for human consumption. This type of contamination may occur at a considerable distance away from the point of discharge, depending upon the local hydrography, climatic conditions and the quality and quantity of the effluent. Frequently there is no visible indication that pollution is present, for usually the water is free from visible evidence of sewage, and interference with the normal growth and reproduction of the shellfish is not apparent.

In these circumstances, if the shellfish are to be exploited, the producer, or in some circumstances the local authority, is required to treat the shellfish by a process which will make them suitable for human consumption. The object of this paper is to describe briefly the factors influencing the pollution of shellfish and to review the methods available for treating them.

FACTORS AFFECTING THE POLLUTION OF SHELLFISH

In England and Wales there are no statutory standards for the quality of sewage effluent discharged into tidal estuaries, and the quality of effluents in these areas usually falls far short of those discharging into freshwater streams. Frequently comminution or screening and sedimentation are the only form of treatment. Even with full treatment employing percolating filters, the effluent may contain many faecal coli. Allen, Brooks and Williams (1949) showed that a coarsely settled

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* Based on an article originally published in 1961 in the Royal Society of Health Journal (Volume 81, Number 3, page 173).

sewage from a well-maintained treatment plant may contain up to 29 700 faecal coli/ml and a fully-treated effluent 4 900 faecal coli/ml. These figures indicate that shellfish pollution cannot be completely eradicated by the improvement of sewage treatment along conventional lines, although the area polluted may be substantially reduced following full treatment of an effluent. In areas where shellfish production is extensive, it is therefore reasonable to expect special steps to be taken to purify sewage effluents to a higher bacterial standard than that usually accepted for effluents discharged into tidal waters. Either chlorination, or lagooning, is available for reducing faecal bacteria to negligible numbers before discharge of an effluent into the sea.

The degree of pollution of an estuary varies greatly from time to time. In particular there is an increase in the pollution of many estuaries during periods of prolonged heavy rain, when the effect of excessive drainage from grazings, the operation of storm overflows, and the flushing of sewers may bring about a great increase in the numbers of faecal organisms entering an estuary.

Once liberated from an outfall, faecal bacteria, including the gastro-intestinal pathogens, are subjected to a variety of different factors which bring about a reduction in their numbers. Dilution with the surrounding sea water may be sufficient for a considerable reduction in the concentration of these bacteria, and provided that the discharge is situated in deep water, or is far enough from commercial shellfish beds, polluting bacteria may not be present in sufficient numbers to render the shellfish of an unsatisfactory bacteriological quality. The dilution factor can be influenced greatly by the tidal velocity, the depth of water over the point of release, and the wind. Where the discharge point is upstream of commercial shellfisheries pollution is generally at a maximum at low tide, when the volume of diluting water is small and tide-locked sewage outfalls are opened (Plate 1). In other areas, pollution of a commercial shellfishery may be evident only on the flood tide.

In addition, other factors such as filter-feeding by small marine animals, sedimentation (Ketchum, Ayres and Vaccaro 1952), natural mortality caused by antibiotic substances present in sea water (Vaccaro et al. 1950), and sunlight (Reynolds 1965, Gameson, Pike and Barrett 1968) may cause substantial seasonal variations in the numbers of polluting bacteria present.

The degree of pollution acquired by molluscan shellfish is also dependent upon the feeding activities of the shellfish themselves. All the species mentioned earlier can become contaminated by the inclusion in the shell-cavity of a sample of grossly polluted water. However, they can also become polluted in lightly polluted water as a result of their feeding activities. In suitable feeding conditions, a current of water is passed through the gills, and suspended food material, including bacteria, is strained off and moved by ciliary activity to the mouth. Under favourable conditions, the European flat oyster may pass more than 4 litres of sea water through its gills in one hour, and in polluted water this will result in a concentration of waterborne bacteria within the gut of the oyster. At 16°C European flat oysters may concentrate up to six times the quantity of faecal bacteria present in the water around them (Wood 1965) (Plate 2). Cockles and mussels are affected similarly, although no precise figures for the bacterial up-take are available.

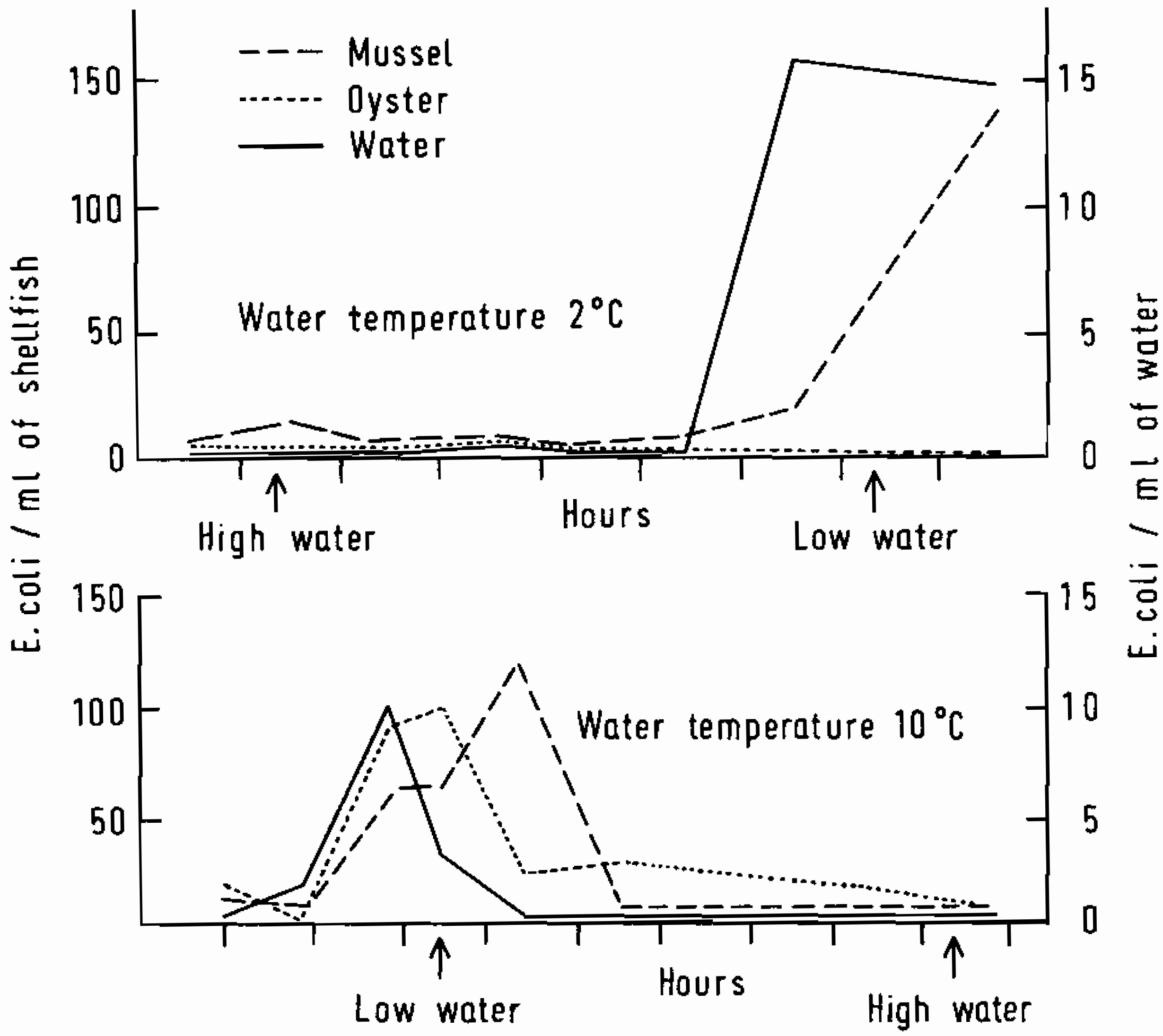

Plate 1 Changes in numbers of faecal bacteria in water, mussels and oysters during one tidal cycle. Pollution was greatest around low water, except for oysters in water of $2^{O}C$.

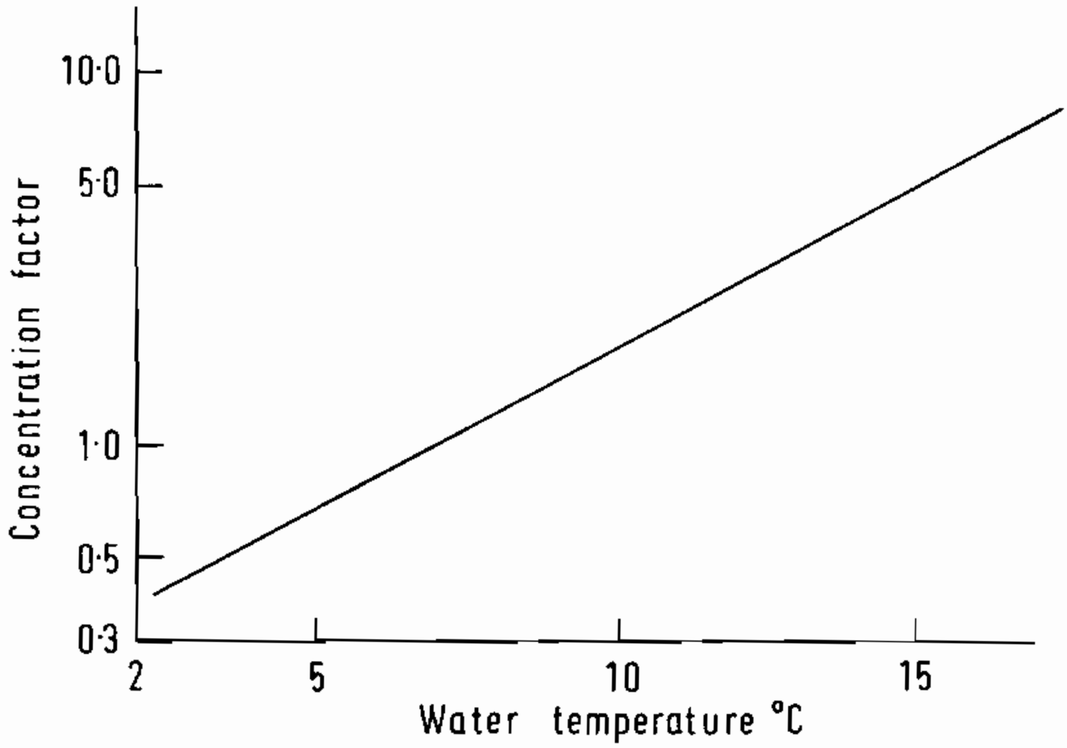

Plate 2 The effect of water temperature on the concentration of E. coli by the European flat oyster.

The rate of water filtration is influenced by water temperature, the volume of water drawn through the shell cavity during the winter being less than in the warm summer months. The filtering rate of oysters is barely detectable at water temperatures below 5°C, and the concentrating effect is not evident (Plate 1); as a result, oysters from grounds known to be lightly polluted may be quite satisfactory for human consumption during the winter months. This effect of temperature has also been noted in Canada (Needler 1941). The same type of variation is also shown in mussels, but to a lesser extent; the effect of a low water temperature upon the feeding of the cockle has not yet been measured, but is likely to be considerable since cockles do not grow during the winter months.

Therefore, in deciding whether or not shellfish from a particular source require to be treated before sale, all these factors must be taken into account. Cockles are normally cooked before sale and offer no serious problem, but before mussels or clams can be marketed the layings may require a careful investigation covering all the tidal and seasonal variations likely to be encountered.

THE REMOVAL OF POLLUTING BACTERIA

Although all the species mentioned may become polluted, many shellfish-producing areas are clean, and the shellfish are suitable for human consumption without special treatment. In some polluted areas, the normal methods of commercial practice, although adopted for convenience of storage and handling, lead to a satisfactory product. Where some special procedure is required to make shellfish safe for human consumption, several techniques are available, the method selected being dependent upon the type of shellfish and the local conditions. The bacteriological standards of Sherwood and Scott Thomson (1953), which were based upon those of the Fishmongers' Company (Knott 1951), were found to be satisfactory over many years. These standards required shellfish taken directly from the water to have an *E. coli* content not greater than 5/ml of tissue when examined by the roll-tube method (Clegg and Sherwood 1947, Reynolds and Wood 1956); shellfish samples containing between 6 and 15 *E. coli*/ml of tissue were regarded with some suspicion, and samples worse than this were considered unsuitable for human consumption. More recently, there has been a move towards higher standards, mainly because a large proportion of mussels and oysters for human consumption pass through some form of purification. Most authorities require the majority of shellfish from a particular source to contain no more than 2 *E. coli*/ml tissue, with only occasional samples containing up to 5/ml. Routine bacteriological analyses have shown repeatedly that a large proportion of samples from a purification plant are free from *E. coli* in 5 ml of tissue; 90 per cent of samples from a mussel purification tank may contain less than 0.9 *E. coli*/ml of tissue (Reynolds 1968), and 97 per cent of oyster samples from commercial oyster purification plants on the east coast of England contain no *E. coli* in 5 ml of tissue (Wood 1963).

The Public Health (Shellfish) Regulations (1934) allow a local authority to permit the sale of shellfish from polluted areas after they have been subjected to one of three basic forms of treatment: sterilization by heat, relaying in clean water, and purification in an approved plant. The methods available to producers for compliance with these regulations will be described by dealing with each of the commercial species in turn. Although not mentioned previously, the periwinkle (*Littorina littorea*) can be conveniently included in this section.

The sterilization of periwinkles

Reynolds (1957) showed that although immersion in boiling water for half-a-minute following the resumption of boiling was sufficient to destroy any coliform bacteria present, at least one-and-a-half-minutes' cooking was necessary to make the flesh extractable. On this evidence, there would seem to be no justification for the inclusion of periwinkles in a closing order.

The sterilization of cockles and mussels

A large proportion of the mussels and cockles landed in this country is eaten after some form of cooking or preservation, so that heat sterilization is a suitable method for removing any polluting organisms. The regulations lay down that sterilization should be carried out by steam under pressure (pressure not stated) for six minutes, in an apparatus approved by the local authority. A full description of the arrangements used for cooking cockles at Leigh-on-Sea, where there is a large cockle industry, has appeared previously (Madeley 1952) (Plate 3). Briefly, cockles held in baskets are placed in cooking pots which receive a supply of steam from a boiler. The steam is allowed to escape from the pot through a vent hole in the base, so that no substantial steam pressure is built up within the pot. After six minutes' steaming the meats are suitably cooked and free from non-sporing waterborne organisms.

For many years, small-scale producers in a number of areas have used open cooking pots containing boiling water, in which the cockles are immersed. Sherwood (1957) showed that the meats of polluted cockles and mussels may be sterilized by continued immersion for one and two minutes respectively after the resumption of boiling. Following this work an order relating to the south side of the Thames (Port of London Health Authority 1957) made provision to include this and other methods as an approved form of heat sterilization.

Both the methods described above produce meats which on leaving the cooker are of a high sanitary quality. However, there is a risk of secondary contamination (Pilsworth 1952), particularly during warm weather, but this can be greatly reduced by improved handling which often results from frequent inspection and sampling of the product by the local authority.

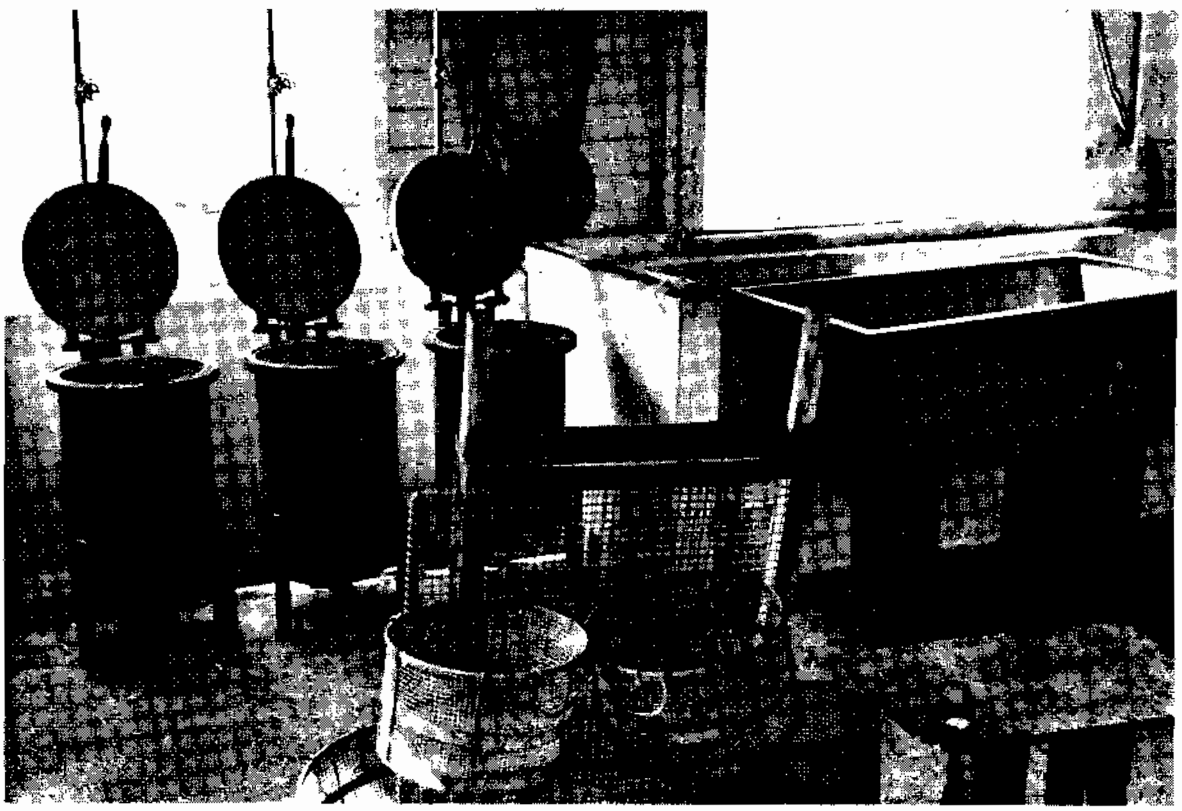

Plate 3 Cockle-processing shed, Leigh-on-Sea, showing cooking pots and baskets for holding cockles during steaming. The riddle (centre) is suspended over the tank (right) in which the meats are collected. (D E Madeley)

The relaying and purification of mussels

Although there is a considerable trade in processed mussels, a large proportion of British landings of mussels taken for food is sent to market in the raw state, and relaying or purification are the main methods used for rendering polluted ones suitable for human consumption.

Relaying is practised as part of good husbandry during cultivation, the young being taken from areas where they settle to situations where they grow and fatten well. Where possible, areas used for relaying should be bacteriologically clean. If a short period of relaying is required to make adult mussels suitable for market, it may be assumed that they have acquired the characteristics of the new area within 48 hours, although in order to ensure that damaged mussels do not remain closed, it is advisable to extend the period of relaying by at least a day or two.

Purification by holding mussels in some form of tank is well-established in this country, following the work of Dodgson (1928) at Conway, where the first purification plant was constructed. He showed that during normal functioning in clean sea water, mussels threw out their polluting organisms within 48 hours, and that these organisms were bound in the mucus threads of the mussel faeces, which prevented repollution of the water. In the commercial Conway plant (Plate 4), sea water is pumped from the sea, sterilized for at least 8 hours by contact with chlorine dosed at the rate of 3 p.p.m. (parts per million), and dechlorinated by sodium thiosulphate. This water is then allowed to run into a concrete treatment tank holding the polluted mussels on wooden grids in a layer 2-3 inches deep. After 24 hours' immersion, the water is drained off, the mussels hosed to remove adhering mussel faeces, the tank flushed out, and a second 24-hour bath given. After hosing and flushing again, the outside of the shell is finally sterilized by covering the mussels for one hour with water containing active chlorine. The mussels are packed in clean bags and sealed before dispatch.

Although the method is entirely satisfactory from the public health aspect, it requires some skill in operation and the provision of both contact and treatment tanks. The procedure may be simplified in areas where only lightly polluted water is available (Reynolds 1956). By placing mussels in this water, their filtering activities first remove bacteria from the water, before they undergo the process of self-purification. In this method only a treatment tank is required, and there is no need for chlorination. A tank working on these principles operated at Teignmouth for several years before the rapid chlorination technique was adopted.

This latter method became available when it was shown that coliform organisms present in sea water were killed after less than 10 minutes' exposure to an added 3 p.p.m. of active chlorine (Reynolds 1959); two commercial plants using rapid chlorination are now in operation. Mussels are laid out in the tank and an amount of stabilized bleaching powder sufficient to give a concentration of 3 p.p.m. of active chlorine is gradually added to the water as it is pumped from the sea into the mussel treatment tank. Sodium thiosulphate is not added, but after about one and a half hours the mussels open and function, the residual chlorine being discharged by the organic matter present. Two 24-hour periods of immersion are used in a manner similar to the Conway technique. The method has proved most satisfactory during several years of operation, and because of its simplicity is likely to find ready acceptance elsewhere.

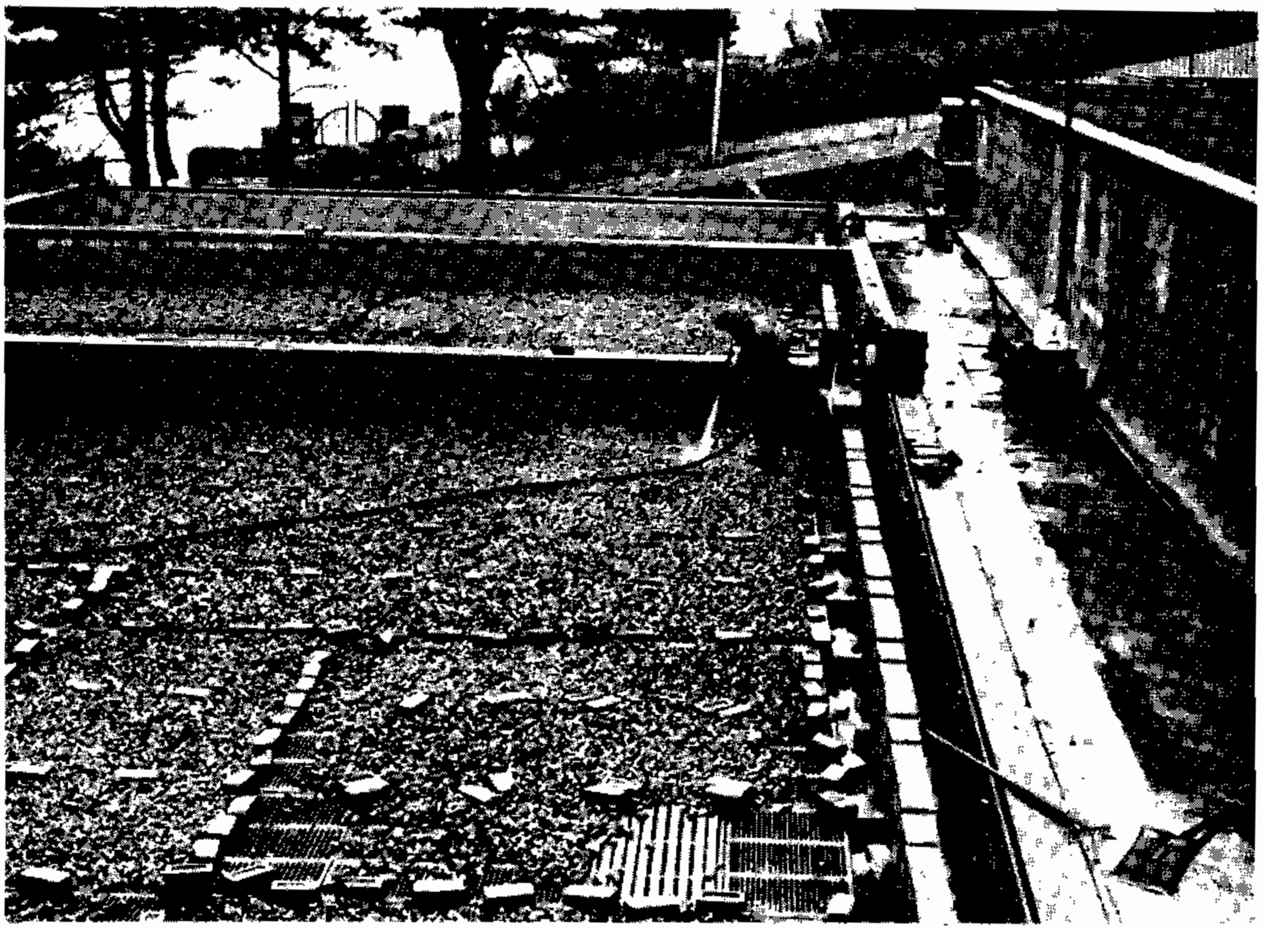

Plate 4 Mussel-cleansing tanks at Conway, showing mussels being hosed, and the supporting grids. On the right can be seen the gutter and penstocks used when flushing the bottom of the tank.

It is important that the water used for shellfish treatment should not be of a salinity below that which shellfish require for self-purification. During excessively wet periods, freshwater run-off into an estuary may cause a substantial reduction of the salinity even at high tide, and care should be taken, in the siting of a purification plant, so as to ensure full salinity during the wet periods. For the purification of mussels, the salinity should not fall below 20.5‰ (parts by weight of salt per thousand); for flat and Portuguese oysters the minimum values are 25.5‰ and 20.5‰ respectively. During wet weather, it is important that the specific gravity is checked when filling the tanks, as cleansing cannot be relied upon to take place at sub-minimal salinities. Fuller details of salinity requirements, including its measurement, have been published in an earlier leaflet in this series (MAFF 1966).

The purification of oysters

Since almost all the oysters produced in this country are consumed uncooked, relaying or tank purification are the only methods satisfactory for the treatment of polluted oysters.

Relaying is practised as part of good cultivation, young oysters being removed from the so-called "spatting" areas to beds where growth and fattening take place. Where possible bacteriologically clean areas are selected. Although the short-term relaying of adult oysters for cleansing may be adopted, this is not generally economic.

Cleansing can take place in pits or basins dug in the intertidal saltings which are used extensively on the east coast for the over-wintering of oysters. Cole (1954) showed that oysters may be purified by laying them in a single layer over the bottom of the pit for periods of two to four days, depending on the water temperature. Where possible, pits should be located in areas free from pollution, but with some care oysters may be purified in pits which are flooded by lightly polluted water at high spring tides, provided that sales are suspended during the period of flooding, or special provision is made to keep out the tide. However, because of the high oxygen demand of oysters during warmer weather, this method can only be used during the cool winter months.

Tanks of a variety of design have been used for the purification of oysters, but only two basic types have been approved by the Ministry of Health for use in closed areas; these use chlorine or ultra-violet radiation for the sterilization of the water. The chlorination technique of Dodgson was used successfully for many years by the local authority at Brightlingsea, where mainly Portuguese oysters were purified. The method is similar in most respects to the Conway technique, except that provision is made for warming the water during the winter months. Originally, the minimum water temperature was 12.2°C (54°F) but this was later reduced to 5°C (41°F) with no loss of efficiency and a considerable saving in the cost of fuel (Wood 1957).

A smaller plant based upon the same principles can handle up to 4 500 oysters per week (Baird 1954). The use of stabilized hypochlorite solution ("Chloros") as a supply of chlorine, instead of the bleaching powder used at Conway, renders the method suitable for operation by unskilled personnel.

The Dodgson system, although working satisfactorily, is not very convenient to operate, particularly for the smaller user. For each cleansing, the tank must be filled twice, and salinity requirements often dictate that this is done near to high tide. For some years now, several privately-operated plants have been running on a system employing a closed circuit in which aeration takes place during circulation, with the result that the sea water can be re-used several times. Ozone has been used as a sterilizing agent, but this requires some skill, for if used in concentrations above the minimum, it can weaken or even kill oysters. Ultra-violet light is suitable for sterilizing sea water, being cheap and simple to handle, non-toxic to shellfish, and leaving no off-flavours in the water. Several privately-owned commercial installations using ultra-violet light have been constructed and are working satisfactorily both on the east and south-west coasts of Britain (MAFF 1961, Wood 1961). Oysters are held in a treatment tank, which for convenience of daily sales is divided into two sections longitudinally (Plate 5). The two tanks (Plate 6) are placed in the circulating system in parallel, water is taken up by a single circulating pump from one end of the two tanks, passed through the ultra-violet sterilizing unit, aerated by a cascade and delivered back to the treatment tanks at the end distant from the pump suction (Plate 8). The tanks are constructed so as to facilitate a good circulation of water, being generally four times as long as their width. An installation consisting of two tanks each 20 ft long by 5 ft wide requires two 30 watt lamps, delivering 14, 4 watts u/v (2537 Å), and a circulation rate of 1 000 gallons per hour. The oysters are held in trays (Plate 7) to facilitate removal, and the total capacity is 10 000, so that for a two-day treatment process the maximum daily output is 5 000. Water is held in the tanks for a maximum of 14 days during winter, and 7 during summer. The coliform population of water of average turbidity is reduced by 99 per cent in 8 hours, but when sea water is taken directly from the sea it may be excessively turbid, and it is therefore circulated through the sterilizer for 24 hours. Whenever oysters are placed in the tank the water is sterilized by 8 hours' circulation beneath the ultra-violet lamps. Where it is desired to have cleansed oysters available each day, untreated oysters are placed in different sections on alternate days, so as to prevent the repollution of oysters which have undergone 24 hours' purification. Aeration of the water is maintained by constant circulation, and the purification of Portuguese oysters can continue during the warmest summer months. Where smaller installations are required a series of asbestos-cement prefabricated tanks may be substituted for the concrete tanks. These tanks are coupled together into two units, which are operated in the same way as described previously. These tanks allow the installation to be extended or modified as required, and have special use where a temporary installation is needed or where the ground is soft and foundations for the larger tanks costly. The results of the bacteriological analyses of oysters which have undergone commercial cleansing in these plants have been comparable with those from any other plant.

Installations employing recirculation in places where natural sea water is not available may use an artificial sea water, made up with five simple salts (MAFF 1966). Several plants of this type have been tested by the Fishmongers' Company and are operating in Billingsgate.

THE LOCAL AUTHORITY'S ROLE

The original Dodgson technique for cleansing shellfish required skilled staff and this led to the construction of large purification units at Conway, Brightlingsea and other places to cater for the whole of the local industry. Nowadays, the move is towards privately-operated units, which have become feasible with the simpler methods of water sterilization by chlorine and ultra-violet light. With the introduction of simpler cleansing units which can be worked by the shellfish producers themselves, the local authority is not usually required to provide these facilities, and the main role of the local authority is now one of normal food quality control by frequent inspection and sampling. In addition, however, the officers of a local authority can perform an important service by educating shellfish producers towards improved methods of handling, purification and sterilization. It is hoped that this short review of the factors affecting the pollution of shellfish, and of the methods available for both sterilization and purification, will help public health officers in this direction. In cases of difficulty the staff of the laboratories of the Ministry of Agriculture, Fisheries and Food at Conway and Burnham-on-Crouch, specializing in these problems, are available for consultation.

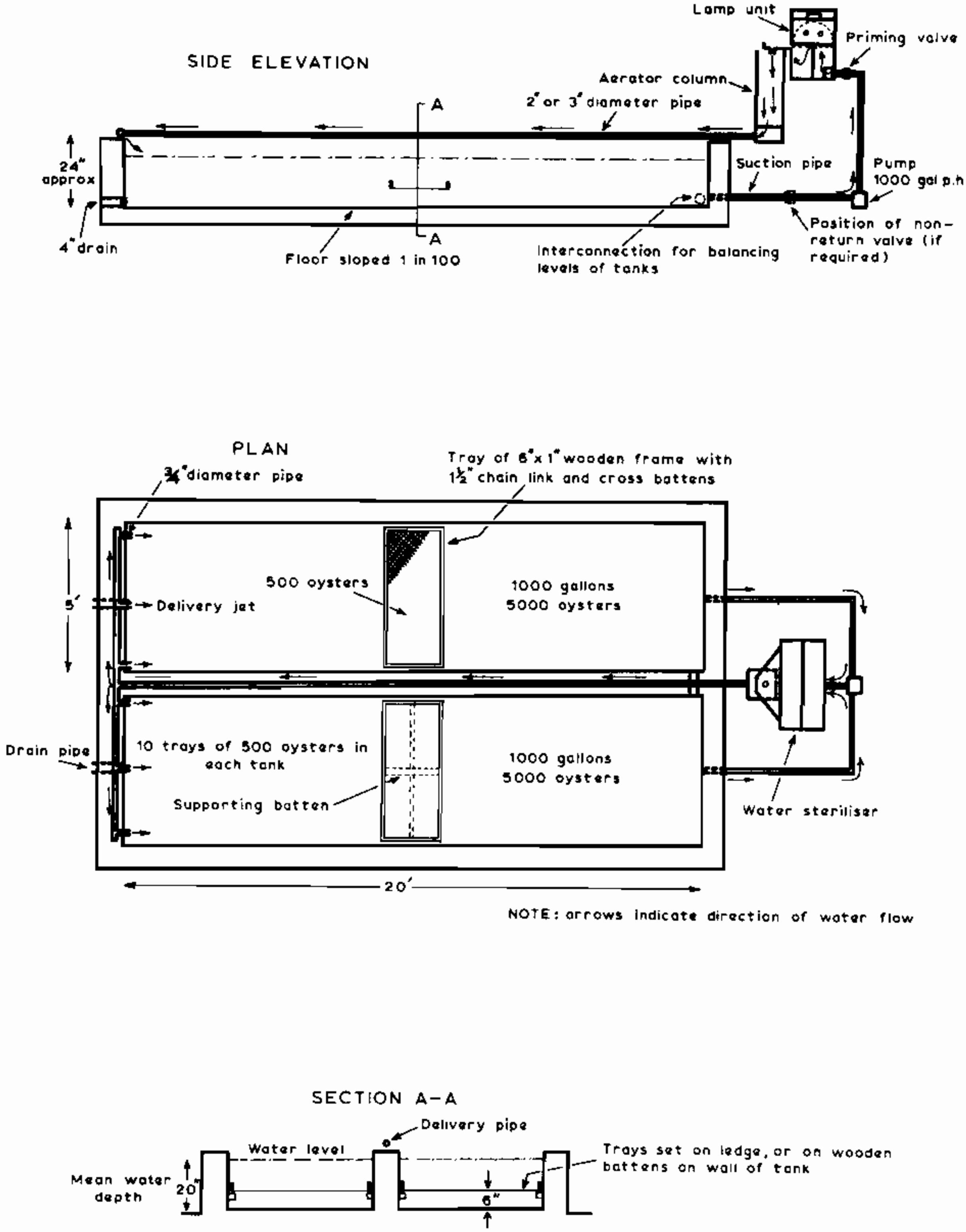

Plate 5 Layout of concrete ultra-violet tanks to cleanse 5 000 oysters per day.

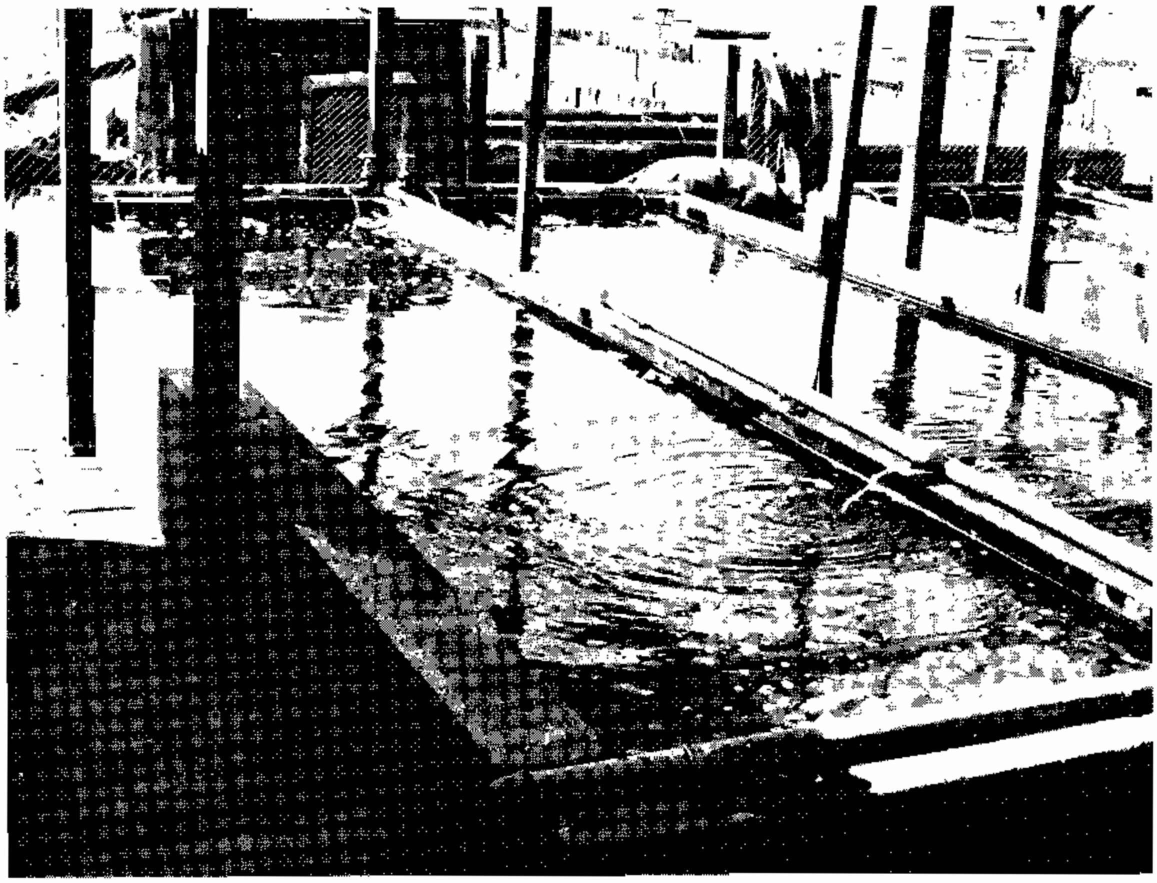

Plate 6 General view of a purification plant using ultra-violet light.

Plate 7 Tray of Portuguese oysters taken from an ultra-violet purification plant.

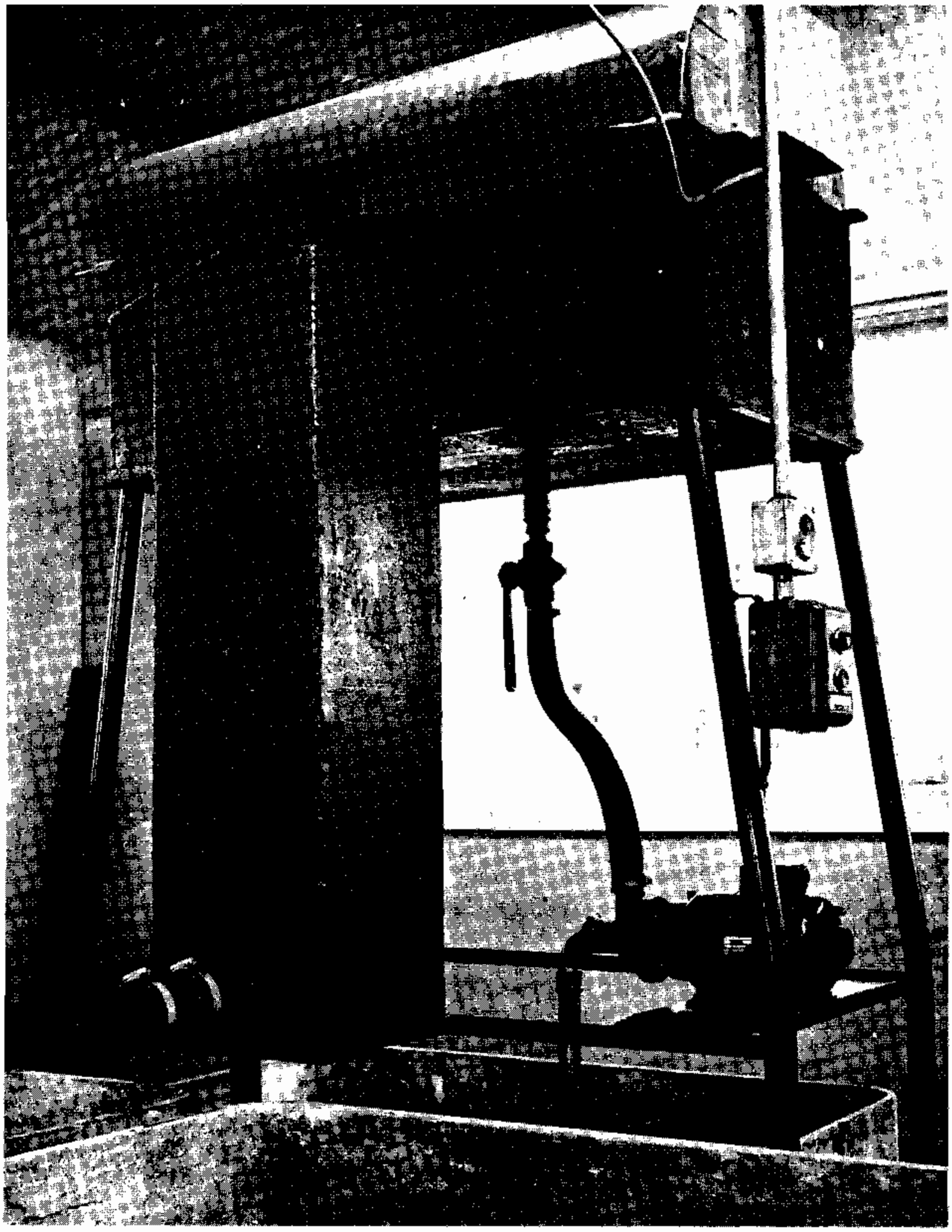

Plate 8 Equipment used in an ultra-violet purification plant, showing circulating pump, water sterilizer and aerator column.

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