

# LRMC and charging the polluter

## The case of industrial waste water in Ireland

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*Ireland is about to embark on a large programme of expansion of waste water facilities. This raises important questions as to payment of the costs, and in particular of the capital costs of plant that will treat industry's effluent. This paper looks at the pricing of waste water services to industrial dischargers, with the aim of applying the broad principles of public utility pricing and of incorporating environmental considerations. After considering the theoretical optimum level of treatment and the polluter-pays principle, economists' recommendations on capacity pricing by utilities are examined, in particular pricing based on long-run marginal cost. An attempt is made to provide a workable method of applying long-run marginal cost pricing to the capital costs of industrial waste water treatment, at present. Preliminary examples of calculated prices are given. We recommend that prices calculated in this manner be announced soon to enable firms to compare the costs of treatment by local authorities with costs of their own treatment or of cleaner production technology, should these options be open to them. Firms will then be able to reserve capacity at the authorities' plants. Investment decisions by authorities and firms can be taken in the light of correct prices, and aquatic quality should be achieved at least cost to the community overall.*

*Keywords:* LRMC; Industrial Waste Water Treatment; Trade Effluent Charges

This paper looks at pricing of waste water services to industrial dischargers in accordance with the broad principles of public utility pricing and incorporating environmental considerations. In the best

of all possible worlds, producers and consumers face prices that reflect the true cost of resources. When this does not happen several important benefits are forgone. The wrong signals are sent out to producers and consumers; too much or too little is produced or consumed; and the community is worse off than it should be. Furthermore, there may be particular sections of society that will be proportionately worse affected than others.

Despite these bad effects, the importance of price is frequently ignored. Many unsatisfactory outcomes are the result of this. So for example when we read a statement like: 'In the Seine-Normandie basin 50% of treatment is believed not to operate'<sup>1</sup> we probably need look no further than price for the explanation. Subsidized capital and inadequate charges are the suspects.

Introducing the environment into the picture merely involves extending the application of pricing principles. While the assimilative capacity of certain areas of the environment was perceived to be limitless, then this assimilative capacity was zero-priced: in many cases correctly perhaps. However, now that the finite or fragile nature of some of the environment's services is becoming evident, it is even more important to devote some effort to the consideration of setting correct prices.

The context of this paper is the proposed large expansion in waste water treatment facilities. This raises important questions as to payment of the capital costs and of the much-increased running costs. The discussion in this paper will proceed as follows. The theoretical optimal level of treatment and pricing of discharges will be described: this theoretical approach has to be our underlying guide. A discussion follows on the much-cited polluter-pays principle and the EC's Urban Waste Water Directive.<sup>2</sup> Next we look at the pricing principles that should be applied by utilities, such as those supplying electricity, a bridge or water services. We

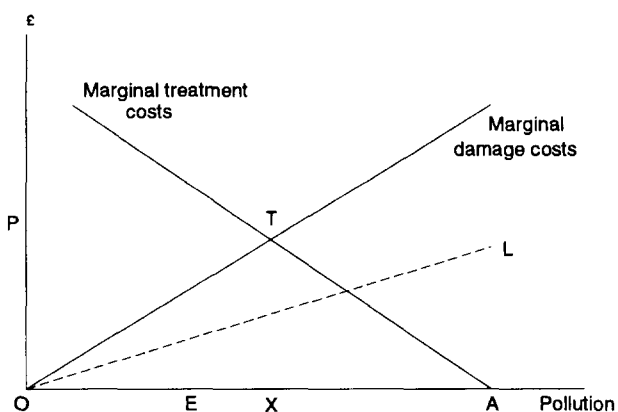
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dwell on the special considerations that affect large capital investments, such as peaks in demand, and on the issue of prevention or abatement by firms themselves versus central provision of treatment. Some experience in different countries or regions will be described. Having discussed the theory, subsequent sections will look at the estimation in Ireland of long-run marginal cost of capacity, and issues arising, before setting out the conclusions.

### Theoretical efficiency

Our starting-point is that the underlying aim of policy is to improve the economic well-being of society. The main focus will be on firms and public authorities, and money and pollution are the commodities that concern us. A firm producing low levels of pollution or discharge may be inflicting very small damage on society. As the absorptive capacity of the receiving medium is increasingly used, further units of discharge will impose higher damage. Assuming that the cost of the damage of each extra unit of discharge can somehow be measured in monetary terms, we can describe a schedule of marginal damage costs, which rises as discharges rise. This is shown in Figure 1.

The firm, perhaps engaging in no pollution prevention or treatment, discharges at an initial level, say at level A. For the firm to reduce pollution by a small amount, it might incur quite a small cost. However, large-scale reductions might incur high costs per unit of pollution reduction. The marginal costs of treatment would tend to rise as successive amounts of pollution are *reduced*. It should be mentioned that the term 'treatment' will also be taken to include the introduction of cleaner production technology, at pre-discharge stage. The marginal cost of treatment schedule is shown along



**Figure 1.** Optimal charges and pollution level, given marginal treatment costs and marginal damage costs.

with the marginal damage cost schedule in Figure 1. Note that movement leftwards along the pollution axis indicates more treatment, or reduction of pollution. Note also that the schedules might be stepped, rather than straight lines.

At level A pollution where there is no treatment, the cost of damage imposed on society is much higher than the cost of treatment, and society as a whole would be better off with less pollution. The benefits of treatment would outweigh the costs, and more treatment is worth undertaking. On the other hand, at level E pollution say, the high level of treatment is unjustified, the costs outweighing the damage costs. Society is better off moving to X, the optimum level of pollution, by means of regulation or the imposition of the optimum charge or tax of OP on the polluter.

At X the damage costs imposed by the firm on society are £OP, and to induce the firm to reduce pollution to this optimum level it should be faced with this same cost, in the form of a tax or charge amounting to £OP pounds per unit of pollution. The firm releasing A amount of pollution has low treatment costs and faces relatively high tax, £OP, per unit of pollution. It will be better off if it treats rather than pays the tax. The firm at E faces OP tax but instead undertakes higher-cost treatment. It will be better off doing less treatment.

Multiplication of the tax or charge per unit of pollution by the number of units of pollution gives the total revenue from the charge: that is, OP multiplied by OX, or the area OPTX, represents the revenue. Similarly, the value of damage done by X units of pollution is triangular area OTX.

Another way to give the firm the same incentives is to offer it a grant or 'bribe' of OP for it not to pollute. The firm forgoes the same sum as in the tax case if it *does* pollute so that the incentives, at least in the short term, are right. In the long term, however, the prospect of receipt of a bribe not to pollute could encourage the establishment of dirty industry, though in practice licences for dirty industry might not be forthcoming. Of course, the advantage of a charge is that it yields revenue, which can be used on treatment by the central agency, or ultimately given to the firm for treatment, or to reduce distortionary taxes. Subsidies by themselves place a burden elsewhere on society. Another method by which X level of pollution is achieved is for the firm to be required to bid for rights to pollute.

These three measures – taxes, bribes or bidding for pollution rights – are economic measures. However, the same optimal level of pollution can also be achieved, if only in static terms, by the

imposition of regulations that stipulate that only level X pollution is allowed. The drawback of regulations, or standards, is that there is no ongoing incentive to reduce pollution once the standard is reached. It is also very wasteful to have both firms that face cheap treatment costs and those that face high treatment costs being required to conform to a standard. The same total level of treatment could have been achieved for less overall cost if the firms with low treatment costs did most treatment, as would be encouraged by a tax. Of course these schedules are likely to vary between firms, industries, locations, time of day and time of year, so that setting the optimal tax or regulation level is an ideal rather than a practical possibility. Approximations have to be made.

Suppose on the other hand, in contrast to the national average that, say, the graph represents, the marginal damage costs schedule in a particular region is rather low, given by OL. This could be due to high local absorptive capacity. Then our original treatment level, and taxes or charges OP, would have been too high. The firm will be worse off than necessary and society could devote too many resources to abatement. Regardless of whether this concept is academic, owing to difficulties with measuring absorptive capacity and the costs of damages, we must still be aware of it. Not merely does this help one to be forewarned, as polluters will make these points, it also helps to inform us on policy, as will be seen later.

Ardent environmentalists will of course want something approaching zero pollution: this probably amounts to arguing that the damage costs are much higher, raising the marginal damage schedule and moving the crossover point, T, leftwards. On the contrary, polluters will claim that damage costs are lower and/or abatement costs are higher, raising the marginal treatment costs schedule, moving the optimum to the right, to a higher level of pollution.

It appears that polluters tend to favour regulations or standards as opposed to taxes, perhaps because they can negotiate a standard that they know they can achieve without too much difficulty but which will probably keep out new entrants. This is especially the case with national limits. Polluters oppose the tax, because even at the optimum level of pollution they still have to pay tax on the X units and can rightly claim that the payment amounts to more than the sum of the damage costs (area PTXO is greater than area OTX). This provokes understandable objections from industry's proponents. It can be viewed as a price for the right to a certain portion of the environment's assimilative capacity.

Pollution taxes, however, have good long-term effects, in that firms that can treat cheaply will do so. Firms that face high treatment costs will undertake less treatment. Overall, treatment is achieved at cheapest cost. In addition, improvements to treatment technology and cleaner production technology are encouraged (though regulations will do that too, up to a point). These improvements bring down the cost of treatment schedule, reducing X and the required level of tax. It also satisfies a view that is gaining ground that taxing a bad thing, such as pollution or smoking, could be better than some of the ways in which revenue is raised at present.<sup>3</sup> In general it is agreed that a combination of standards and taxes is the most realistic solution.

Of course the real difficulty lies in estimating the cost of damage. How does one value the damage to a beach or a river? How many people would use it were it not polluted, and how does one value the existence of animal life in the waters, without provoking an argument? Researchers have confronted these questions, for example, by using expenditure on travel as a surrogate for how much people value a recreation that is not marketed. Other approaches have involved estimation of people's willingness to pay. Recent decades have seen tremendous development in these methods, but there remain what are euphemistically called 'tasks for future research'.<sup>4</sup> In a compendium of valuation studies, Magnussen<sup>5</sup> values the social benefits of a 50% reduction in Norwegian nutrient leaching to the North Sea, as proposed in the North Sea Plan. The study aimed to elicit the maximum amount that people would be willing to pay in *increased* sewerage taxes annually. The increase per household worked out at between £50 and £200 and thereby gives a measure of the damage.

Clearly this is not a perfect situation. One is talking about imposing a tax on the basis of an intersection of two curves, one of which is hard to measure, let alone agree on. That said, it is still the correct concept that should be held in mind if we wish to avoid the costs outweighing the benefits, or potential net benefits forgone. The alternative is to impose a regulated limit on pollution, which entails similar uncertainty. It is, however, the polluter-pays principle that is more widely cited and to which we now turn.

### The polluter-pays principle

Measurement problems obviously make implementation of the theoretical ideal difficult. A further obstacle is the penalties that pollution taxes would impose on firms trading in international markets,

unless such taxes were widespread. The Organization for Economic Cooperation and Development (OECD), having the expansion of world trade as one of its main objectives, published *The Polluter Pays Principle* in 1975.<sup>6</sup> Regarded as something of a classic, the publication's important guiding principle is:

that the polluter should bear the expenses of carrying out... measures decided by public authorities to ensure that the environment is in an acceptable state.

And:

The notion of 'an acceptable state' decided by public authorities, implies that through a collective choice and with respect to the limited information available, the advantage of a further reduction in the residual social damage involved is considered as being smaller than the social cost of further prevention and control.

This is in fact the same as our definition of efficient level of abatement given above. OECD states that implementation of the polluter-pays principle may be by various means, such as standards, regulations, prohibitions and pollution charges, or charges to cover the costs of collective waste-treatment plants. To prevent distortions to trade and investment, OECD recommends that:

Member countries continue to collaborate and work closely together in striving for uniform observance of the Polluter Pays Principle, and therefore that as a general rule they should not assist the polluters in bearing the costs of pollution control whether by means of subsidies, tax advantages or other measures.

And they recommend that:

any such assistance for pollution control be strictly limited... where severe difficulties would otherwise occur... to well-defined transitional periods, laid down in advance.

The Foreword makes the important point that the principle does not mean

that the polluter should merely pay the cost of measures to prevent pollution,

implying that even where no cost is incurred in prevention, the polluter should still pay, as occurs in the Netherlands and Germany, among other places.

At about the same time, the EC Council published its Recommendations,<sup>7</sup> which are broadly similar though with difference of emphasis. Charges should be fixed so that primarily they fulfil their incentive function to reduce pollution and do so as

cheaply as possible and make polluters pay their share of costs: the redistribution function.

Having dealt a little with the theory and then with some of the ensuing recommendations by international bodies we can turn to current issues, starting with the EC Directive on urban waste water treatment.

### **The EC Directive**

The Council Directive concerning waste water treatment<sup>8</sup> requires that member states ensure that all agglomerations are provided with collecting systems for urban waste water, and that before discharge they be subject to secondary treatment or an equivalent. The end of the year 2000 or 2005, depending on numbers of population equivalent, are the dates by which these measures must be implemented. The disposal of sludge to surface waters by dumping from ships, by discharge from pipelines or by other means must be phased out by the end of 1998.

The Directive could require some areas to be at a level of pollution reduction that is more strict than the theoretical efficiency levels: that is, rather than move us to X amount of pollution, we are required to abate more than efficiency would indicate, to a lower level of pollution, at point E, say. Even though there is difficulty in estimating the damage function, or no one has actually put a value on the damage to Ireland's waters, some would view these requirements as fairly stringent. The Directive's regulations relating to waste water from the food sector, for example, amount to a harmonization that does not differentiate between levels of assimilative capacity of the local environment.<sup>9</sup> Mainland European countries in effect have higher marginal damage schedules, so that point E is indeed their efficient level of pollution, but it may not be applicable everywhere.

Another angle might be that it is the EC's desire to see uniform levels of treatment prevailing throughout Europe as a matter of principle, in which case then Europe should pay for any 'excess quality'. In fact Cohesion Funds will be subsidizing the municipal part of treatment plants; however, that part of the plant that treats industrial effluent will not qualify for subsidies by the EU on account of restrictions on State aids to industry.<sup>10</sup> In the event, large schemes will be subject to cost-benefit analyses, which ought to ensure that benefits outweigh costs. These studies should leave aside the fact that EU Cohesion Funds will finance a large share of the capital costs of these projects, because there are many projects competing for grants. Many projects will be forgone, including presumably many

worthwhile projects. So, it is argued, the grant to a particular project is not costless because it costs the project forgone: therefore analyses ought to ignore the grants.

### Pricing principles

The programme of enhancement in waste water treatment will incur sizeable capital and current costs, and we need to address the question as to who should pay and how much. First, however, we shall deal with three side issues that could possibly, at least in theory, go some way towards relieving some of the local authorities' financial burdens incurred by this programme.

As already discussed in the above section the programme of enhancements could be more stringent than efficiency would require. Society should aim for level X pollution but in fact may be required to go to the more stringent level E. There may not be a large excess in expenditure involved, but if there is, it could be argued that this excess should be taken outside the 'physical environment account' altogether. It can be argued that the excess is being incurred so that a country can conform to an EU rule. It would constitute a cost in order that the country be *communautaire* and derive positive externalities. Such action is in the nation's interests as a whole. Therefore, the costs ought to be paid by the nation as a whole, rather than by any particular section of the population. Payment for it could be regarded as something similar to member countries' contributions to EU funds.

A second side issue concerns 'free-riders', or people who get off without paying, who ought to pay. We need to ask periodically whether all the major users of waste water treatment are correctly identified and charged. For example, in the UK it is estimated that in some regions up to 25% of the volume of waste water being treated in fact comes from roads, and that it carries sizeable pollution from cars, in the form of lead, rubber and so on. There is a case to be made for charging vehicle users for this service. Making some allowance for use by pedestrians, a correct charge on waste water running off highways would cover at least 10% of volumetric-based costs as well as some of the other costs of the treatment agency. One gains the impression on reading reports by OFWAT<sup>11</sup> that it would like to see motorists pay, but that there is a legal impediment. Be that as it may, the highways are drained for vehicles, which pollute the water. There is no logical reason why an exception to the polluter-pays principle should be made for motorists. It would be worth our while to review the situation to see if any

other illogical exceptions are made, the removal of which could help defray expenses and remove unjustified cross-subsidization.

Thirdly, we have the situation where polluters that discharge to waters where the discharge is not treated pay no charge except a nominal monitoring fee. Non-point pollution – mainly but not exclusively from farming – also needs to be addressed, as it may help to explain the increase in eutrophication.<sup>12</sup> The polluter-pays principle is contravened, in so far as the damage costs are frequently high. As mentioned, charges on trade effluent to waters, rather than just for treatment services, are raised in several other countries.

We shall now address the more conventional issues in pricing, namely the charges for the capital and running costs of waste water treatment plants. There is considerable experience with charging for *running* costs. Many authorities use some system of charging, such as the Mogden formula, originally recommended by the National Water Council, described in "Code of Practice for Control of Trade Effluent Drainage to Public Sewers" by Yorkshire Water Authority, Leeds, January 1976 which sometimes includes an element of capital charge and which breaks down the charge into various components of costs such as flow, concentrations of different pollutants and quantity of settleable solids. Where adequately formulated, charges for running costs appear to be functioning well, except that concern is occasionally voiced that such formulae are difficult for some people to understand. We shall not consider further the formulation of operating charges and will concentrate on the *capital* charges.

Ideally, to pay for the capital cost, an important part of the charge should be calculated by reference to the customer's demand at peak times. The price per unit of capacity should be the cost of making an extra unit of capacity available to the user, or the marginal cost: this is to ensure that users are faced at the margin by the true resource cost of their actions. In addition, when there is a rise or decline in consumption, the supplier can be assured that these are signals to expand or contract, being based on correct prices, not on subsidized or exaggerated prices. Appendix 1 shows how marginal cost pricing maximizes society's welfare.

However, marginal cost varies a great deal, depending on whether one is about to build a new plant, or one has a plant with spare capacity, or the plant is operating at full capacity. Reasonably stable prices are desirable. Therefore, it is usually advised that treatment plants smooth the price somewhat, by reflecting the *long-run* price of incremental capacity. This has the advantage that customers will not face widely different prices caused by their order

of arrival. One method is to use cost per unit of treatment capacity of the next plant to be built. This is long-run marginal cost pricing, or LRMC pricing. The cost can be charged as an annualized value, or up-front in a few instalments, depending on factors such as risk or problems of financing. When such long-run marginal cost pricing results in a surplus or shortfall in required payment to the treatment agency, the difference can be made up either by adjustments to the fixed charge in the customer's tariff (in order to minimize distortions to incentives) or by flows between the agency and national or local government.

In practice, of course, long-run marginal cost pricing is not so widely used, though some utilities profess to be using an approximation to it. Others may say that they are not, but in fact are reflecting LRMC considerations in their tariffs. The impression gained is that there is wide variation in capital charging practice, some agencies receiving grants for their capital and charging the net of grant average cost. Examples are France and the USA, in conflict with the polluter-pays principle. Charges are frequently well short of marginal cost.

This can have repercussions. Being specific to capital, grants can cause extra supply of treatment plant to be built when it might be optimal to charge users correctly, thereby checking unrestrained demand for treatment. In relation to grants, OECD<sup>13</sup> remarks:

Because demand management measures seldom attract government subsidies (unlike supply-expansion schemes in many countries), there will often appear to be a financial advantage in following the supply-expansion route.

In addition, OECD suspects that a high grant could encourage the construction of plant with high running costs. Correlations given in a report of the US Congressional Budget Office<sup>14</sup> suggest that increasing the 'local' share (non-federal, non-state) of treatment plant capital costs from 25% to 45% would reduce lifetime unit costs by between 11% and 43%. The implication is that when the agency is paying the full cost, which will ultimately have to be recouped from the customer, requirements are more modest. However, the main lesson to be learned is not so much that subsidies be avoided but that their application should aim not to be distorting.

It might be informative to digress to a famous conundrum arising with the issue of charging for large capital projects. Known as 'the bridge',<sup>15</sup> the argument is made that:

A free bridge costs no more to construct than a toll bridge, and costs less to operate; but society, which must pay the cost in some way or other, gets far more benefit from the bridge if it is free, since in this case it will be more used.

There is some merit in this argument, but few examples in life are exactly like this one. Indeed the bridge, like a treatment plant, if not inefficiently large, will on occasions become congested, and be subject to peak uses. Peak charging, which reflects the marginal cost of building extra capacity, is then justified. Prior to building, careful calculation of a peak and non-peak tariff could reduce the size of bridge required. There exists some combination of tariffs that could actually ensure that the peaks are so smoothed that there is no unused capacity: hence requiring a smaller bridge, or treatment plant, and saving construction resources. However, the tariff for inducing people to cross the bridge at night would probably have to be negative. You would need to pay people to cross at night or offer them credit against day trips. While not wishing to pursue this example too far, it highlights the importance of charging a higher price when capacity is tight. This applies to the time of day, time of year and indeed in spatial terms as well.

So when it comes to charges for waste water treatment used by new or expanding firms in different locations in Ireland, these should reflect the tightness of capacity. Where there is no spare capacity, the capital charge should in general be higher than where there is plenty of spare capacity. This will have the desirable effect of spatial optimization. New firms are then encouraged to establish in areas where new plant will not be required, thus saving on resources. At the same time it will have the undesirable effect that firms in different regions will be treated differently. However, if equity is desired between regions some form of compensation would be required, and it is preferable that such compensation, if forthcoming, should not affect the charge for treatment capacity.

On the subject of peak pricing in practice, it appears that to undertake this properly would require a level of sophistication in the metering and charging system such that costs would far outweigh the benefits.<sup>16</sup> However, we recall that metering for electricity at different times of day was uneconomic until not so long ago and that now there is a growing number of time-of-day meters in use. In fact some forms of peak charging are used in waste water treatment. For example, in France a firm's average daily load in the month of maximum activity is the base of the firm's charge. In the Netherlands a 20% reduction on the volume charge was proposed (though apparently not implemented, for legal reasons) if 45% or more of the volume were discharged equally between 7.00 at night and 7.00 in the morning.<sup>17</sup> Firms that might store effluent in lagoons and spread the load over a longer period could pay correspondingly lower charges.

Homing in further on the incentive effect, we explained how ideally treatment should be undertaken at the stage where it can be carried out most cheaply. If firms can treat, or they can alter technology, more cheaply than the central agency can, then the charging system should and can encourage them to do so. In terms of our initial diagram, this will happen if their cost of treatment schedule is below that of the central agency's and if the central agency is correctly charging pollution at price *OP*, the agency's marginal treatment cost.

It is interesting to see whether in practice the charges levied abroad are in fact incentives of this kind. We learn that in France in 1979 the charges to industry were a quarter only of the agencies' treatment costs. Even allowing for the subsidies received by industry for pollution control, the incentive effect was not much stronger. The subsidies also come in for criticism for contravening the polluter-pays principle. However, it is reported that they usefully placed projects to reduce pollution 'on the agenda' by encouraging managers to put these projects to their boards of directors.

This system of charges was introduced in France in 1968 with the aim of ultimately equating charges with the social costs of pollution (ie the hard-to-measure schedule of damage costs mentioned at the outset). A recent conclusion, however, is that the charges do not generally attain an effective rate, which may be taken to mean that they usually do not induce pre-discharge treatment where appropriate.<sup>18</sup> This situation may change as charges in France are being raised in stages.

Charges in the Netherlands, Germany, the UK and Denmark are considerably higher. The last two countries' water services receive no state subsidies. Geographical variations in charges are wide in France, but in the UK the range would be narrower, owing to the standardization in pricing imposed by OFWAT.

Ultimately it is difficult to make comparisons between countries. Ideally, one would like to be able to compare, for a given resulting quality of environment, the total costs actually incurred. Then one could see whether the costs vary with level and type of charging system or, indeed, with charging system versus a system of regulations only, as in Japan. However, controlling for 'a given quality of environment' makes this an elusive goal. Different countries have different assimilative characteristics and therefore different costs.

However, within a country, we can look to see what the response to charging policies has been. If over time the response to the introduction of a charge, or to a rise in charge, is that discharges are

reduced, then at least we can speculate that there is an incentive effect. This presupposes of course that there is also adequate monitoring to ensure that disposal by unauthorized means is not increasing. There is also the possibility that the reduction in discharges was the result of some other cause.

Despite these reservations, the evidence is reasonably convincing. In the Netherlands, for example, biodegradable discharges are reported to have been reduced dramatically from 40 million PE (or population equivalents, a measure of pollution or capacity) to 11.4 million PE between 1969 and 1985. According to OECD<sup>19</sup> this is generally attributed to charges, which increased very rapidly in the 1970s, although permits are required for all discharges, which would also have had an effect. Chemicals, food, beverages and tobacco firms installed extra pre-discharge treatment. The pulp and paper industries reduced discharges from 2.5 million to 1.5 million PE in four years in the early 1970s.

Apparently, from the USA and Canada there is clear evidence of the effects of trade effluent charging schemes in reducing waste water flows, waste concentrations and also derived demands made upon the public water supply. In addition, specific responses have been observed. For example, volume-only charges used to be widespread in parts of the USA so that firms had an incentive to introduce in-factory recycling systems. The result was highly concentrated effluent, which was difficult for sewage works to treat effectively.<sup>20</sup>

Denmark provides us with another interesting example, which may have useful lessons in situations where high rises in charges are envisaged, as in Ireland. In a plant in Copenhagen the new charge on waste water pollution induced firms to reduce effluent load to below half the projected level, with similar effects on revenue. Consequently, in planning upgrades of plant to include nutrient removal, the agency is involving the industrial dischargers from the outset. Future charges are explained to firms so that they can react and state their estimated requirement for services, which for one treatment plant represented a 99% decrease on current amounts discharged.<sup>21</sup> In effect the local authority and firms were planning as a single unit and seeking jointly to find the most efficient solution.

### **Issues in industrial waste water treatment in Ireland**

Having discussed some aspects of theory that are relevant to the issue of industrial waste water treat-

ment and its effect on aquatic quality, we should now ask what are the implications in practice. What in particular are the implications for policy, given the requirements of the EC Directive on urban waste water treatment? As a result of this Directive, the authorities are required to have installed secondary waste water treatment on a wide scale in two phases by 2005. The extra or upgraded municipal and industrial capacity that is proposed is estimated at some 4 million PE<sup>22</sup> and could cost in the region of £630 million.<sup>23</sup>

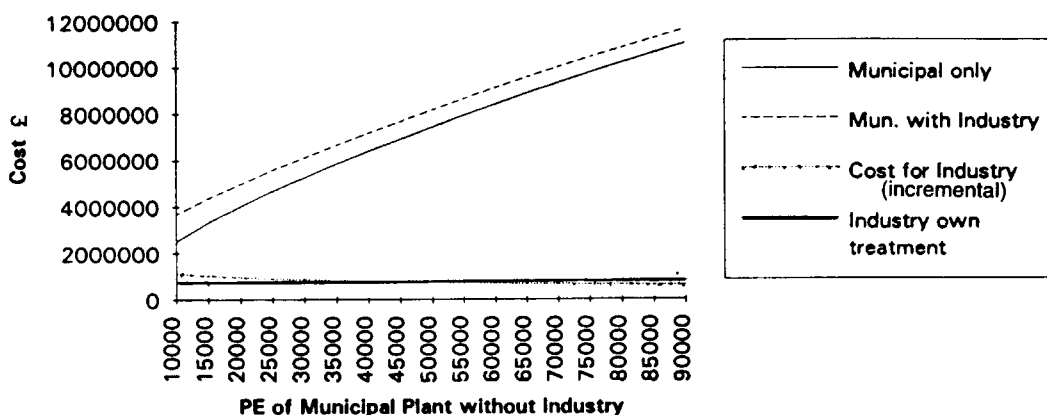
As mentioned, while EU Cohesion Funds will be made available for the municipal requirements, the Community guidelines on state aid for environmental protection and increasing attention to the polluter-pays principle imply that treatment of industrial effluent should be self-financing, whether treatment is central or undertaken by the firm on site. Charging by local authorities (of which there are 88) for the service that they provide to industry is therefore required. The first part of this paper would caution central authorities to have regard to the demand-dampening effects of new charges. Prior to construction of plant it is important for them to establish what would in fact be the magnitudes of own treatment and/or introduction of cleaner technology by firms when faced with the local authority's new charges. Where these options would

be more cheaply undertaken by the firm than by the central agency, then they should be undertaken at firm level, provided of course that adequate monitoring and its financing are catered for. However, the task of researching firms' costs of possible own treatment and alternative technology, in many cases before these firms have had to consider it themselves, makes the task less than straightforward. Nevertheless, the authorities do need to know the extent to which firms are likely to undertake their own treatment or install cleaner technology, so that the authorities avoid building excess capacity.

One check that authorities can undertake to gauge the correct amount of capacity is by using information on relative costs, so that they can judge the amount of pollution that firms will want to have treated centrally versus the amount they would more economically treat themselves. This entails having a good knowledge of the relative costs of treatment by firms and by sanitary authorities. Incidentally, though we are not concentrating on these, the *operating* costs for firms on the one hand and for municipal plants on the other, though subject to some economies of scale, are broadly similar. This similarity stems from the high share of fuel in operating costs.

From persons familiar with both treatment by firms and public sector treatment, it is possible to

**Capital Cost of Industrial Effluent Treatment**



Industrial Load	
Flow	3333 m <sup>3</sup> /day (5 day week)
Peak factor	1
Load	800 kg BOD/day (5 day week)
Conc.	240.024 mg/l BOD

PE	
Organic	13,333
Hydraulic	4,830

**Figure 2.** Capital costs of municipal plant and incremental costs of plant to treat a specific industrial load – comparison of incremental costs with own treatment costs. See text for explanation.

Source: G O'Donoghue, personal communication, Department of the Environment, Dublin, 1994.



obtain information on the capital costs of own treatment and to compare these with the capital costs of adding a firm's treatment to the municipal plant. An example of such a comparison<sup>24</sup> is given in Figure 2. The second highest curve shows the capital costs of central plants of different capacity, with PE ranging from 10 000 to 90 000. The highest curve shows the total capital cost of central treatment plant if industry or a specific firm with 13 333 PE organic load and 4830 hydraulic load is added to the central plant. Lower down on the graph are shown both these incremental costs of adding the firm to central plant of different sizes and the firm's cost of own treatment, the latter drawn as a line in order that the crossover point can be gauged. (The firm's line only indicates the firm's cost at the size specified. The horizontal axis refers to size of municipal plant only, not to the size of the firm's treatment plant.) A cross-over point occurs when the municipal plant is about 45 000 PE. The specified firm can self-treat more cheaply where the municipal plant is small: that is, less than 45 000 PE. On the other hand, this firm's load can be more cheaply treated by the municipal plant if the municipal plant is bigger than about 45 000 PE. Other examples for industry or firms with different effluent flows and loads are given in Appendix 2.

The general thrust of the analysis is twofold: that it is cheaper for a firm to join the central or municipal plant when the municipal plant is large relative to the firm's load, but that the cross-over point also depends on a relationship where the flow and pollution load interact to affect costs. These examples are illustrative and cover only capacity costs of treatment.

In the case of the numerous small treatment plants of under 15 000 PE that are proposed, it may only be economic for firms with small loads of perhaps under 6000 PE with low hydraulic flow to use the municipal plant. In the case of the proposed medium-sized plants of about 40 000 PE, it would only be economic for firms discharging less than perhaps 13 000 PE to use the central plant. By contrast, with the five proposed big plants of over 100 000 PE, only firms with very large pollution loads would treat their own waste water more economically. Obviously the actual relative costs would need to be investigated on a case-by-case basis. Furthermore, the piping costs for transporting effluent to the central plant have not been addressed here. They would be specific to the firm and can sometimes add the same capital cost again.

There are other considerations that might be important to firms: for example, their potential liability for pollution damage might be reduced if

they discharged to the central system (though this has not been tried in the courts), or firms might not wish to have treatment on site. These considerations apart, it would be possible to make rough estimates of how much of the central treatment capacity firms would want to use, when charges are in place, but it would be a lengthy task to estimate this with any certainty.

Fortunately, there is an easier way to approach the question. This is simply for the sanitary authorities to announce correct prices, as soon as possible, so that firms can indicate the capacity that they require. The correct cost information will then be conveyed to firms and the correct outcome should then be achieved in the sense that firms can plan to undertake own treatment where it is cheaper to do so, or to change their technology, if it is cheaper. In this way aquatic quality is achieved at cheapest overall cost to the nation.

The long lead times required for investment in altered plant or technology make it important that firms be flagged in advance of the introduction of the correct charging, and that they have a clear idea of how the charge would affect them for the foreseeable future. Firms that are confronted with this price will then be in a position to cost the options confronting them. The remainder of this paper will consider what is the correct price that the central treatment agencies should charge. For reasons stated above, the emphasis will be on the capital costs of treatment plant, as collection and conveyance costs tend to be location-specific and might need to be calculated on a case-by-case basis.

### **What price should central treatment agencies charge?**

A few words are in order to describe the present system of charging in the 88 sanitary authorities. There is no standard charging procedure, and the result is that the situation varies from one authority to another.<sup>25</sup> *Current* costs of industrial waste water treatment are charged by some authorities, probably about half. The current charges are in some cases based on water intake and, in at least 18 authorities, based on pollution content with implementation of a charging formula like the Mogden formula.

Where *capital* costs are concerned, from a survey,<sup>26</sup> we know that 12 authorities – that is, about a seventh of all authorities – have received or are about to receive a capital contribution from firms. Over the years this contribution by firms will have amounted to a total of £23 million, compared with state capital expenditure over the last 10 years of

approximately £400 million, of which well over £50 million was for industrial waste water treatment. It is clear therefore that the charging system to date has been distorting by undercharging the pollution of most firms.

Turning now to consider the correct charging scheme that should be adopted, as we saw earlier, long-run marginal cost (LRMC) pricing is advocated for capacity costs. It is however when attempting to implement LRMC pricing that one feels the advocates, who are mainly economists, have been largely unsupportive: they talk about it and believe in it in theory but put little effort into convincing utility managers that it is worthwhile in practice, or indeed into showing them a straightforward way to use it.

The calculations are clarified, to an extent only, in documents such as the Working Paper of the World Bank,<sup>27</sup> but the sheer range of types of long-run measures would not instil confidence. This range is seen in Figure 3, reproduced from the World Bank Working Paper, derived on the basis of certain assumptions.

The extreme variability of short-run marginal costs (or textbook marginal cost, denoted TMC in the graph) is what long-run marginal costs aim to avoid. The smoothing effect of using long-run measures is to ensure that firms arriving immediately before a large new capital investment, or immediately after, are faced with similar charges, because in the long run a similar cost is incurred on behalf of each of them. In addition to removing unfairness between firms on the timing front, a

smoothed price enables any firm to plan ahead with less uncertainty and with correct indications of the long-run resource costs of its use of the central facility.

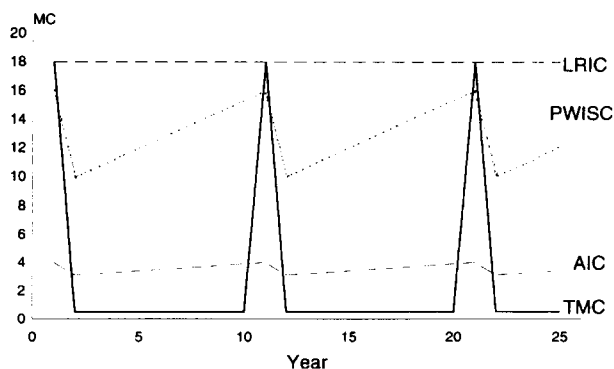
Similarly, the utility knows that its customers are paying true long-run resource costs, so that if demand rises this is a true signal to the utility that capacity should indeed be increased. Customers have indicated that they are willing to pay for it. This is an improvement on the situation where a service is subsidized, and where naturally demand is likely to be higher than what customers are willing to pay for: so the authorities have to consider expansion earlier than otherwise, and have to make some justification for extra outlays in the face of many similar 'urgent' demands for other (perhaps subsidized) services.

Briefly, there are three long-run measures shown in the graph. At the top is *long-run incremental cost* (LRIC), which involves charging the (equivalent annual) cost per unit of treatment supplied by the next item of investment: this is apparently a suitable measure where lumpiness is not such a problem. Next is the *present worth of incremental system cost* (PWISC), in which one calculates the incremental total cost of bringing forward by one year an extra unit of consumption of the service. The lowest is the *average incremental cost* (AIC), which is the present worth of the investment stream divided by the present worth of the stream of resulting incremental output.

Another variant of LRMC, used by Herrington<sup>28</sup> in a few applications in water services and not illustrated here, is the *average marginal incremental cost*, or AMIC, in which the present worths of an expansion scheme and of another slightly higher or lower expansion scheme are calculated. Their difference is then divided by the present worth of the difference in quantities of service.

The seeming low level of adoption of LRMC pricing stems largely from a perception that people are not sure how to calculate it and that, while it satisfies the allocative function of price, it fails to satisfy cost recovery. The latter is a surprising concern in view of the fact that cost recovery has not been widely applied in any case. In order to balance the books, a further charge is therefore required, which is perceived as troublesome. There is perhaps also the belief that the form that the price takes doesn't make much difference. These are the three main reasons, though several spurious reasons are also given by objectors, according to OECD.<sup>29</sup> One might expect the UK water regulator to endorse the estimation of LRMC for pricing; however, OFWAT is ambivalent, stating:<sup>30</sup>

Investment every 10 years  
Stable costs case



**Figure 3.** Prices based on various measures of marginal cost. TMC: textbook marginal cost (short run); LRIC: long-run incremental cost; PWISC: present worth of incremental system cost; AIC: average incremental cost.

Source: World Bank.

OFWAT wishes to encourage this type of work. However, experience demonstrates that such estimates are much influenced by the underlying assumptions, in particular the area over which costs are calculated, and liable to upset by changes in circumstances.

Many of these reservations have been echoed recently<sup>31</sup> by consultants with experience in the water services industry in the UK and elsewhere. However, at least two water service companies in the UK use a rough-and-ready calculation of LRMC. In addition, volumetric tariffs in one water service company in the North of England, which has large excess capacity, are being reduced while the standing charge element is being increased. Conversely, a company in the South has high LRMC and is raising the volumetric charge and lowering the standing charge. These instances in fact apply to water supply, where the tariff is simpler in any case. However, it can be seen that, actually, there is an underlying instinct, at least where conditions are extreme, to set prices broadly in line with LRMC.

What pricing system then would we advise a utility to implement? In the circumstances, it may be more fruitful at this stage to aim modestly at *basin prices on the notion of LRMC* and to have it appear very simple. How could this in practice be implemented in Ireland today? One possibility is as follows.

If one had a relationship that expressed the capital cost as a function of the plant size:

$$\text{Cost} = f(\text{Capacity})$$

then the first derivative of cost with respect to capacity would be a reasonable approximation to AMIC, described above. Such an approximate relationship is in fact available, using recent experience<sup>32</sup> in Ireland as a guide.<sup>33</sup> While such relationships are subject to revision, it serves our purposes as an example:

$$\text{Cost} = 2500 \text{ PE}^{0.75}$$

Taking logs, this gives:

$$\ln \text{Cost} = 7.824 + 0.75 \ln \text{PE}$$

The derivative of  $\ln \text{Cost}$  with respect to  $\ln \text{PE}$  is 0.75, which is the elasticity of cost with respect to PE. It implies that a 10% increase in capacity raises capital costs by 7.5%, and as:

$$\text{Elasticity} = \text{Marginal cost} / \text{Average cost} = 0.75$$

then the marginal cost of an extra PE = 0.75 times the average cost per PE.

The costs covered in the estimation include mechanical and electrical costs and exclude civil works. However, it appears that civil works would exhibit similar economies of scale. This estimated equation can be used to cost the proposed plants listed in the strategy study of sludge treatment.<sup>34</sup> In Table 1 the proposed plants have been broken down into just two groups – small and large plants – for the sake of simplicity. With the aid of the formula, their marginal costs per PE have been calculated and are shown in the final column.

We see that the marginal cost per extra unit of capacity is about £124 per PE, for Ireland as a whole. On account of economies of scale, however, for the small plants that are proposed the marginal cost would be £172.50, and for the large plants it would be £105.50. In order to implement LRMC pricing, something based on these figures should be the price that is presented to firms as the price of the central treatment capacity that they reserve.

It is interesting to compare these figures with recent proposals made in a report to DG XI.<sup>35</sup> In the context of a scenario called INT, in which environmental objectives are integrated into sectoral economic policies, a charge on effluents discharged to *surface waters* is outlined (p 163):

The INT scenario assumes the imposition throughout the EU of a charge on effluents by manufacturing industry into surface waters... The level of the charge was based upon the charge levels in the

**Table 1. Estimated marginal cost of capacity, per PE**

Plants	Number of plants	Average size of plant (PE)	Average cost per plant (£m)	Average cost per PE (£)	Marginal cost per PE (£)
Small	81	13 969	3.2	230.00	172.50
Large	5	350 315 <sup>a</sup>	40.5 <sup>a</sup>	111.40	105.50
Total	86	29 797 <sup>a</sup>	5.0 <sup>a</sup>	144.00	124.00 <sup>b</sup>

*Notes:*

<sup>a</sup>Average size of plant and average cost per plant exclude Ringsend, which is estimated to be 1 565 818 PE.

<sup>b</sup>Weighted by total PE in each size category.

The relationship given is assumed to be applicable for plants up to 100 000 PE, beyond which size economies of scale may no longer arise. For plants over 100 000 PE it is assumed that the marginal cost for each PE unit over 100 000 remains constant, and consequently the ratio of marginal cost to average cost rises. Total proposed capacity as given by Weston-FTA is 4 098 580 PE for all plants combined.

Dutch water effluent charging system, and was set at ECU 23 per pollution equivalent (p.e.) in 1995 (converted in purchasing power present parity equivalents in all Member States), gradually rising to ECU 30/p.e. in the year 2000 and remaining stable afterwards. The phase-in of the charge over a number of years allows for an announcement effect in industry, which enables companies to minimize the *ex post* cost of the measures.

These proposals amount to £18.70 and £24.40 per PE in 1994 and 2000 respectively and are for discharge to surface waters – that is, not to treatment – though one assumes that they would be set at a level that is comparable with treatment costs. It is interesting to compare them with our figures. Our marginal capacity charges, if annualized over, say, 20 years at 5%, amount to £8.50 and £13.80 for the large and small installations respectively. So our prices are rather lower but do not include collection, conveyance and operating costs. Our prices therefore would at least appear to be reasonable in relation to those proposed in DG XI's report, which being based on Dutch figures would tend to be high by European standards.

Actual total capacity charges in Ireland could of course be higher than those calculated here, insofar as marginal cost pricing would only recover some 75% of average capital costs per PE. The authorities might raise the remaining 25% in a variety of ways. It should be raised in as undistorting a way as possible and could be left to the discretion of the authority, be it via industrial rates, via a further charge on treatment or whatever. Far from being a drawback of long-run marginal cost pricing, this local discretion could be seen as an advantage. Local authorities would be enabled to reflect local conditions in this other part of the charge, such as tight or excess capacity, or the desire to attract firms by annualizing this part of the charge over a longer period.

### Breakdown of capital charges by polluting elements

The analysis so far has been simplified, for purposes of exposition, by the assumption that industry's effluent can be simply characterized in terms of PE alone. PE is a useful measure of the pollution strength of effluent, being the organic biodegradable load having a five-day biochemical oxygen demand (BOD) of 60 g of oxygen per day.<sup>36</sup> However, industry's effluent contains differing mixes of polluting ingredients (as well as other ingredients not dealt with here). While household waste water will conform to a fairly standard mix of pollutants, firms

will have a varied mix, so that each firm's capital implications for the treatment plant could be different. Three important elements to be considered are the maximum rate of flow, the COD load, and the suspended solids load (where COD is chemical oxygen demand, a measure increasingly preferred to BOD. 1 g BOD/day can in some circumstances be taken as equivalent to 2 g COD/day approximately, before treatment). A similar capital cost relationship to that given above, but with the three elements separated out, is estimated<sup>37</sup> as follows:

$$\text{Cost} = 2001F^{0.75} + 2452C^{0.75} + 3489S^{0.75}$$

where  $F$  is the maximum flowrate (m<sup>3</sup>/day),  $C$  is the COD load (kg/day), and  $S$  is the suspended solids load (kg/day).

Similar economies of scale prevail as in the aggregate equation given previously, as shown by the uniform exponent, and marginal cost is still 75% of average cost, for each element. We shall illustrate the breakdown with the example of the small treatment plants from above, where the average size was just under 14 000 PE. Assuming typical loads<sup>38</sup> per PE, this plant's capacity can be described in disaggregated form as a flowrate of 9513 m<sup>3</sup>/day, 1676 kg COD/day and 1048 kg SS/day, so that the capital cost of the plant is:

$$\begin{aligned} \text{Cost} &= 2001 \times 9513^{0.75} + 2453 \times 1676^{0.75} + 3489 \\ &\quad \times 1048^{0.75} \\ &= 1\,927\,442 + 642\,363 + 642\,497 \\ &= \text{£}3.2 \text{ million} \end{aligned}$$

(which is the same cost as given in Table 1 above).

For this treatment plant the average and marginal capital costs for each element of capacity can then be calculated. They are given in Table 2.

By way of illustration therefore, a firm, such as a small meat or dairy plant, reserving the following capacity at this plant:

200 m<sup>3</sup>/day  
400 kg COD/day  
300 kg suspended solids/day

being charged the marginal costs given in Table 2, would pay:

$$\begin{aligned} \text{Cost of firm's} \\ \text{reserve capacity} &= 200 \times 152 + 400 \times \\ &\quad 287 + 300 \times 460 \\ &= \text{£}283\,200. \end{aligned}$$

In other words, if it paid the cost in one go, the firm would pay about £0.28 million. If the amount were annualized over 20 years at 5% discount rate, the annual capital charge would be just under £23 000.

**Table 2. Estimated average and marginal capacity cost of each element (£)**

	per m <sup>3</sup> /day maximum flow	per kg COD/day	per kg SS/day
Average cost	203	383	613
Marginal cost	152	287	460

Note: Applies to a typical small plant, of just under 14 000 PE.

## Charging method

We have demonstrated a method for deriving a charge for capacity, based on the notion of long-run marginal cost, and have given an example of the charge for capacity. At present the price is expressed per unit of treatment capacity, which is relevant to the way that firms express their requirements when negotiating with the sanitary authorities. There are still several issues that ought to be addressed, but will only be touched on here.

One of the issues is the problem of risk to the treatment authority when it incurs heavy outlays on behalf of a firm. The firm may for some reason be unable to pay, leaving the authority with heavy debts. In Ireland, as we saw, some firms are required to pay an up-front contribution. An alternative is for the firm to be required to sign a legal guarantee to pay this charge, spread out over a few years, perhaps through recourse to a risk intermediary.

Risk apart, there are at least two possible main methods of payment: (a) payment for capacity reserved annually, and (b) payment for flow. In the first method, the firm is required to pay the capital charge according to the capacity it reserves. This practice would tend not to be followed extensively, for reasons of habit and the potential upheavals of change probably. Lothian in Scotland applies this method. It encourages firms to review the treatment capacity they reserve, perhaps stimulating them to undertake serious assessment of their potential for pollution reduction on a regular basis.

The second method derives from the desire to give a continuous, rather than annual, incentive to pollution reduction, by charging on each unit of pollution rather than on capacity reserved. The charge would be per cubic metre and per kg. This method is used in Copenhagen, Severn Trent and Northern Ireland, for example. To the extent that it actually promotes further pollution reduction, it poses a corresponding financial risk to the treatment authorities: that is, unless the authority raises the per-unit charge on the remaining pollution, including on that of other customers, to make up lost

income. There is a more serious drawback. Strictly speaking it is not the throughput that affects capacity requirements, but demand at peak times. So the charge ought to be applied on peak days, assuming adequate metering of flow and pollution.

Theoretically, the two methods would then amount to the same thing, though in practice the different timing of firms' decisions could have an effect. Reserving capacity is a big annual decision, whereas payment on amounts discharged entails continuous decisions about discharge levels. The question is open as to which method to use. However, there could be an argument for (a); that is, for applying the charge to the capacity which the firm reserves annually, as illustrated in our calculated example in this paper. There is a particular advantage in Ireland at present, because a programme of construction is in the initial planning stage. Realistic demands for capacity can be signalled by firms. It will also stimulate the firm, while considering the annual bill, to assess its capacity requirements for the following year and thereby provide annual information to the local authority. In any event, the current operating and maintenance costs will be charged on a flow basis, thus providing the continuous incentive to reduce consumption, if that is considered desirable.

## Summary and recommendations

- The theoretical criterion for the welfare of society should be kept in mind: that at the margin, treatment costs should not outweigh damage costs, and pollution charges should be related to damage or treatment costs.
- The polluter-pays principle is a practical approach to the theory, for trading nations to apply. It is also a requirement of the EU. Application helps to reduce unfair advantages in the form of subsidies being given to firms in some countries. However, some nations will have a natural advantage in terms of assimilative capacity.
- Good pricing practices are feasible; they are implemented to some extent and in various forms in other countries; and they have noticeable incentive effects.
- Industry, consisting of large point dischargers, is the immediate area for the establishment of correct pollution-related prices. This is not to deny the urgency of the need to address the non-point pollution damage from agriculture.
- Attention should be given to charging the free-riders, in particular agricultural dischargers and highway users.

- More benefits will ensue and less pain, if the price structure encourages pre-discharge or cleaner technology alterations, where these are cheaper.
- Transition to higher charges will be smoother and firms will be able to make good decisions, on pre-discharge and cleaner technology alterations, if they have an idea of likely charges.
- Correct charging requires basing the price on long-run marginal cost principles. This has not been widely adopted, perhaps because it appeared to be unnecessarily complicated. However, a simpler approach based on the notion of LRMC was shown to be not only feasible but also to have desirable features.
- Preliminary estimates of charges for industrial effluent based on the notion of LRMC were calculated for Ireland. These estimates are expressed per unit of treatment capacity in terms of PE reserved. They have also been estimated per unit of treatment capacity, disaggregated into pollution components: that is, per cubic metre per day of maximum flow, and per kg per day of COD and suspended solids.

The author is grateful to Gerry O'Donoghue for providing the examples of technical relationships used in this paper, to Patrick Honohan for advice of a practical and theoretical nature, to Martin O'Donoghue for useful insights, and to John Lawlor for his analysis of the current situation. The author is responsible for any errors that remain. An earlier version of this paper was presented at the Fifth Annual Conference of the European Association of Environmental and Resource Economists (EAERE) held in University College, Dublin, Ireland, 22–24 June 1994.

<sup>1</sup>The Polluter-Pays Principle: definition analysis implementation, OECD, Paris, 1975.

<sup>2</sup>Council Directive of 21 May 1991 regarding urban waste water treatment', *Official Journal of the European Communities*, No 1 135/40, 30 May 1991.

<sup>3</sup>F Cairncross, *Costing the Earth*, Economist Books/Business Books, London, 1991.

<sup>4</sup>P-O Johansson, 'Valuing environmental damage', in D Helm, *Economic Policy Towards the Environment*, Blackwell, Oxford, 1991, 111–136.

<sup>5</sup>K Magnussen, 'Valuing reduced water pollution using the contingent valuation method – testing for mental accounts and amenity misspecification', in S Navrud (ed), *Pricing the European Environment*, Oxford University Press, New York, 1992, 195–230.

<sup>6</sup>OECD, *op cit*, ref 1.

<sup>7</sup>Council Recommendation of 3rd March 1975 regarding cost allocation and action by public authorities on environmental matters', *Official Journal of the European Communities*, No 1 194/1, 25 July 1975.

<sup>8</sup>EC, *op cit*, ref 2.

<sup>9</sup>J Kilgallon, 'Environmental control in the Irish food industry – EC context', in J Feehan (ed), *Environment and Development in Ireland*, Environmental Institute, University College Dublin, 1991, 143–147.

<sup>10</sup>'Community guidelines on State aid for environmental protection' (94/C 72/03), *Official Journal of the European Communities*, No C 72/3, 10 March 1994.

<sup>11</sup>'Current Water and Sewage Charges' (Annex 3) and 'Structure of Costs' (Annex 4) in *Paying For Water: a time for decisions*, OFWAT, Birmingham, 1990.

<sup>12</sup>F J Convery and C-E Mercier, 'Opportunities for river basin planning in Ireland: lessons from French experience', background paper to Water for Life Conference, RDS, Dublin, 9 October 1992.

<sup>13</sup>*Water Resource Management: integrated policies*, OECD, Paris, 1989.

<sup>14</sup>*Study of Lifecycle Wastewater Treatment Costs*, US Congressional Budget Office, 1985; referred to in OECD, *op cit*, ref 13, p 79.

<sup>15</sup>H Hotelling, 'The general welfare in relation to problems of taxation and of railway and utility rates', *Econometrica*, Vol 6, 1938, p 242–269.

<sup>16</sup>OECD, *op cit*, ref 13.

<sup>17</sup>B C Leech, *Charging for Discharges to Water*, Department of the Environment, Dublin, 1986.

<sup>18</sup>OECD, *op cit*, ref 13.

<sup>19</sup>*Ibid*.

<sup>20</sup>OFWAT, *op cit*, ref 11.

<sup>21</sup>P S Nielsen, 'Experience in waste water treatment, (including implications for industry)', paper presented at a training course for local authority staff on the management of water and sewage treatment plants, Department of the Environment, Dublin, 1993.

<sup>22</sup>Weston-FTA Ltd, *Strategy Study on Options for the Treatment of Sewage Sludge in Ireland, Vol 1, Department of the Environment, Dublin, 1993*.

<sup>23</sup>Department of the Environment, An Environmental Action Programme, Dublin, 1990.

<sup>24</sup>G O'Donoghue, personal communication, Department of the Environment, Dublin, 1994.

<sup>25</sup>J O' Flynn, *Trade Effluent Charging: a local authority view*, The Institute of Water and Environmental Management, University College Cork, 1988.

<sup>26</sup>S Scott and J Lawlor, *Waste Water Services: Charging Industry the Capital Costs*, Policy Research Series Paper No 22, Economic and Social Research Institute, Dublin, 1994.

<sup>27</sup>*Alternative Concepts of Marginal Cost for Public Utility Pricing: Problems of Application in the Water Supply Sector*, World Bank Staff Working Paper No 259, 1977

<sup>28</sup>P Herrington, *Pricing of Water Services*, OECD Environment Programme, Paris, 1987.

<sup>29</sup>*Ibid*.

<sup>30</sup>OFWAT, *op cit*, ref 11.

<sup>31</sup>Scott and Lawlor, *op cit*, ref 26.

<sup>32</sup>This relationship is loosely based on an earlier regression analysis of ten plants, ranging in size from 10 000 to 18 000 PE, with resulting  $R^2 = 0.67$  and standard error of the coefficient = 4.09.

<sup>33</sup>O'Donoghue, *op cit*, ref 24.

<sup>34</sup>Weston-FTA Ltd, *op cit*, ref 22.

<sup>35</sup>DG XI, *The Potential Benefits of Integration of Environmental and Economic Policies – An Incentive-based Approach to Policy Integration*, European Communities Environmental Policy Series, Graham & Trotman, London, and Office for Official Publications of the European Communities, Luxembourg, 1994.

<sup>36</sup>EC, *op cit*, ref 2.

<sup>37</sup>O'Donoghue, *op cit*, ref 24.

<sup>38</sup>For calculation purposes, 1 PE is assumed to be associated with the following loads: hydraulic, 1 PE = 0.227 m<sup>3</sup>/day average (dry weather flow, DWF) and 0.681 m<sup>3</sup>/day peak flow (= 3 DWF); organic, 1 = 0.12 kg COD/day; solids, 1 PE = 0.075 kg suspended solids/day.

<sup>39</sup>M G Webb 1976. *Pricing Policies for Public Enterprises*, Macmillan Studies in Economics.

## Appendix 1

### How marginal cost pricing maximizes society's welfare

Society wishes to maximize net welfare gain from a project, such as a waste water treatment plant. Setting externalities aside, net welfare is the difference between total benefit and total cost, so that the aim is expressed as follows:

maximize: welfare = total benefit – total cost

In turn, total benefit is the sum of total revenue of the treatment plant and the consumers' surplus of its customers, giving:

maximize: welfare = total revenue + consumers surplus – total cost

or, using symbols:

maximize:  $W = TR + CS - TC$

or

$$W = (TR - TC) + CS$$

which is producers' surplus plus consumers' surplus, all these variables being functions of the level of service or output,  $Q$ .

To maximize welfare,  $W$  is differentiated with respect to output  $Q$  and the result is set equal to zero, giving us

the conditions for an optimum, thus:

$$\frac{dW}{dQ} = \frac{d(TR + CS)}{dQ} - \frac{d(TC)}{dQ} = 0.$$

The demand curve is  $P(Q)$  and  $TR + CS$  is the area under the demand curve or the integral over 0 to  $Q$  of  $P(Q)dQ$ . The derivative of the integral of  $P(Q)$  is  $P(Q)$ , this being the resulting first term on the right-hand side.

The derivative of total cost is marginal cost,  $MC$ .

The condition for the optimum therefore is:

$$\frac{dW}{dQ} = P(Q) - MC = 0$$

or

$$P(Q) = MC.$$

This says that price is set to marginal cost.

Second-order conditions will show that this optimum is a maximum. We therefore have maximum welfare gain where the consumers' valuation of the last unit produced equals the marginal cost or benefits of the resources foregone.<sup>39</sup>

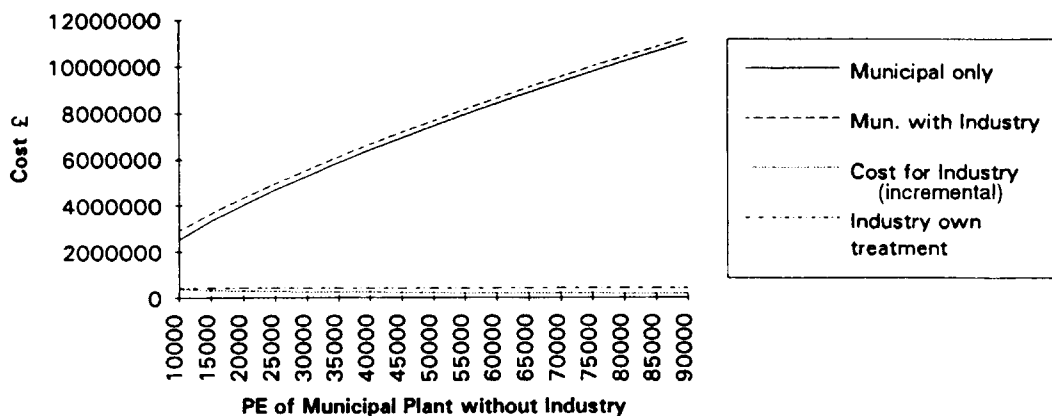
## Appendix 2

Further examples of capital costs of municipal plant and incremental costs of plant to treat a specific industrial load – comparison of incremental costs with own treatment costs.

Source: G O'Donoghue, personal communication, Department of the Environment, Dublin, 1994.

Note: Costs of treatment plant include land and exclude sewer mains.

Capital Cost of Industrial Effluent Treatment



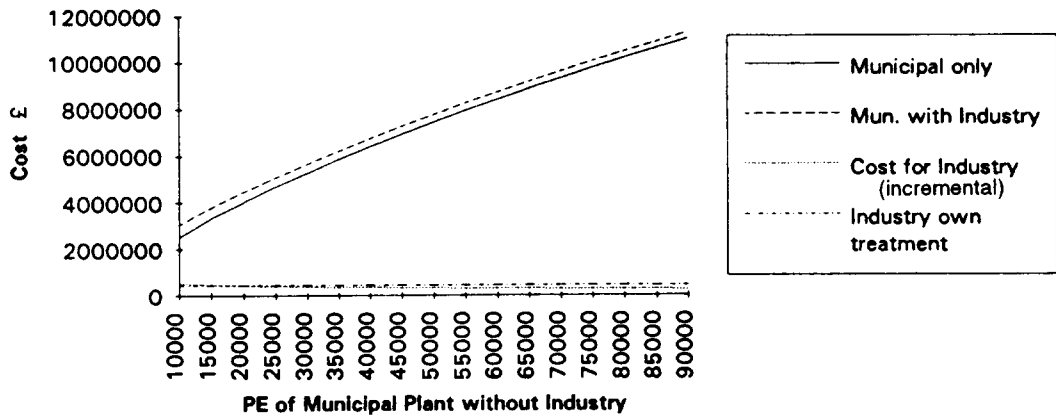
#### Industrial Load

Flow	1000 m <sup>3</sup> /day (5 day week)
Peak factor	1
Load	240 kg BOD/day (5 day week)
Conc.	240 mg/l BOD

#### PE

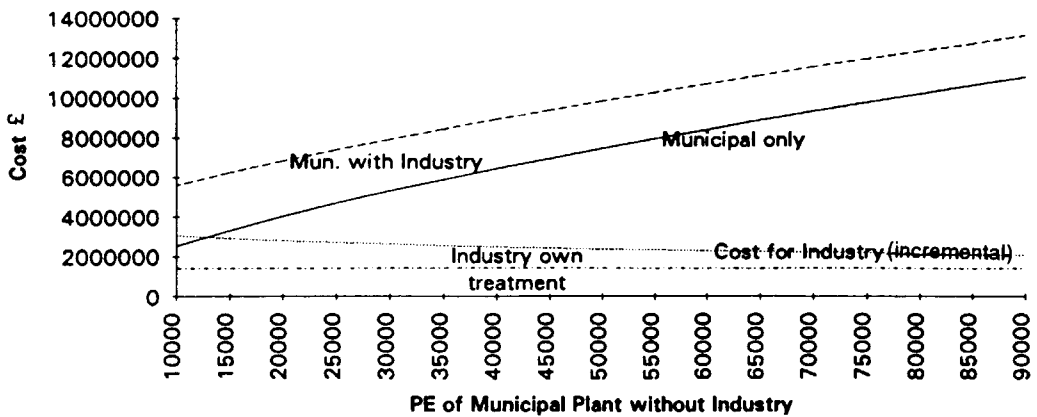
Organic	4,000
Hydraulic	1,449

**Capital Cost of Industrial Effluent Treatment**



<b>Industrial Load</b>		<b>PE</b>	
Flow	1000 m3/day (5 day week)	Organic	4,000
Peak factor	2	Hydraulic	2,899
Load	240 kg BOD/day (5 day week)		
Conc.	240 mg/l BOD		

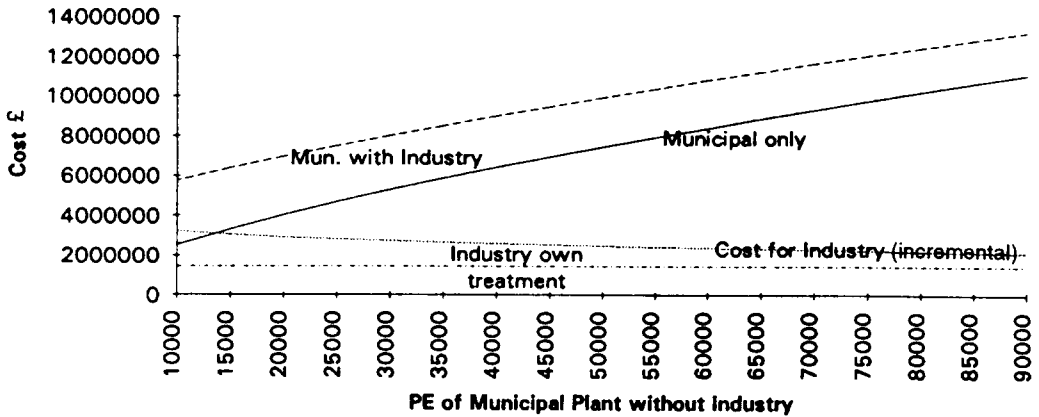
**Capital Cost of Industrial Effluent Treatment**



<b>Industrial Load</b>		<b>PE</b>	
Flow	1000 m3/day (5 day week)	Organic	83.333
Peak factor	1	Hydraulic	1,449
Load	5000 kg BOD/day (5 day week)		
Conc.	5000 mg/l BOD		



**Capital Cost of Industrial Effluent Treatment**



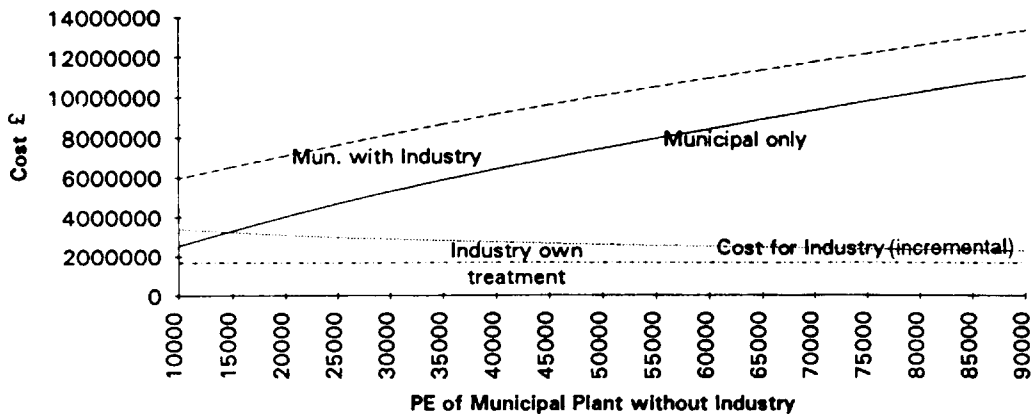
**Industrial Load**

Flow 1000 m3/day (5 day week)  
 Peak factor 2  
 Load 5000 kg BOD/day (5 day week)  
 Conc. 5000 mg/l BOD

**PE**

Organic 83,333  
 Hydraulic 2,899

**Capital Cost of Industrial Effluent Treatment**



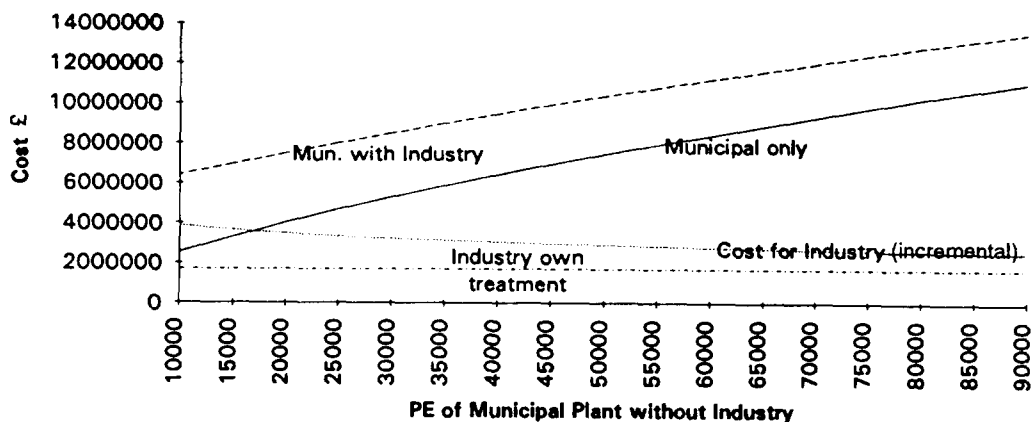
**Industrial Load**

Flow 3333 m3/day (5 day week)  
 Peak factor 1  
 Load 5000 kg BOD/day (5 day week)  
 Conc. 1500.15 mg/l BOD

**PE**

Organic 83,333  
 Hydraulic 4,830

### Capital Cost of Industrial Effluent Treatment



**Industrial Load**

Flow 3333 m3/day (5 day week)  
 Peak factor 2  
 Load 5000 kg BOD/day (5 day week)  
 Conc. 1500.15 mg/l BOD

**PE**

Organic 83,333  
 Hydraulic 9,661