PROJECT 310 R+D NOTE 16

New Style Charging Schemes for Discharges and Abstractions

London Economics
R&D Note 16

NRA

National Rivers Authority

New Style Charging Schemes for Discharges and Abstractions

London Economics
91 New Cavendish Street
London W1M 7FS

National Rivers Authority
Rivers House
Waterside Drive
Aztec West
Almondsbury
Bristol
BS12 2UD

R&D Note 16

Publisher
National Rivers Authority
Rivers House
Waterside Drive
Aztec West
Almondsbury
Bristol
BS12 2UD

Tel : 0454 624400
Fax : 0454 624409

First Published 1991

Dissemination Status
Internal: Restricted
External: Restricted

Research Contractor
This document was produced under R&D Contract 310 by:

London Economics
91 New Cavendish Street
London W1M 7FS

Tel: 071 436 2991
Fax: 071 436 2638

NRA Project Leader
The NRA's Project Leader for R&D Contract 310 was:

Dr Jan Pentreath - Head Office

Additional copies
Additional copies may be obtained from R&D section of NRA Head Office.

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SUMMARY

The NRA commissioned this report to examine the arguments for the use of economic instruments, such as tradeable permits or incentive charges, in the regulation of abstractions to and discharges from controlled waters. The report's key objectives are:

- to identify the principles which should underlie the use of economic instruments; and
- to examine the alternative uses of any excess revenue raised by economic instruments.

The report provides a self-contained reference on the principles and issues associated with the use of economic instruments, and it focuses on economic principles. The report's key findings are:

- tradeable permits have limited applicability and probably cannot form the basis of a national charging scheme;
- pollution charges in combination with existing licences and consents could lead to a significant improvement in the effectiveness of environmental regulation.

Pollution charges should reflect the impact of dischargers and abstractors on water quality. The report proposes a matrix of weights reflecting the factors that determine the impact of discharges and abstractions on water quality. A particular firm would pay a charge determined by multiplying its impact weight by a unit price. It is recommended that unit prices are set for each river catchment, rather than nationally. A major advantage of this approach is that it could be achieved by a simple extension of the existing NRA charging scheme.

Unit prices must be set in order to meet environmental standards. This requires that they reflect firms' abatement costs. However, abatement costs are not fully known by the NRA. To address this it is recommended that charges are initially set at a relatively low level and progressively increased by an RPI+K rule until WQSs are met. This has the advantage of providing a reasonable transition period and will encourage firms to invest in abatement technology.

It is recommended that the NRA continues to levy a separate charge to recover administrative costs as part of a two part tariff to ensure that it meets its revenue requirement. The retention of a charge for consent applications is recommended to recover costs incurred by the NRA.

Incentive based charging would probably generate revenue in excess of the NRA's administrative costs. The report considers a number of alternative uses for this revenue.

KEY WORDS

Damage costs, abatement costs, market-based instrument (MBI), regulatory instrument (RI), information requirements, pollution charge, tradeable permit, impact matrix, Water Quality Standards (WQSs), Uniform Emission Standards (UESs)

1. INTRODUCTION

This report examines how economic instruments can be used in the control of abstractions from and discharges to controlled waters. The terms of reference of the report are attached in Appendix 5. The three key objectives of the project were:

- to examine the arguments for the use of incentive-based charging systems by the NRA to help control abstractions from and discharges to controlled waters;

- to identify the principles which should underlie the setting of incentive-based charges; and

- to examine the alternative uses of any excess income raised by charges.

In addressing these issues we were asked to prepare a report which should both stimulate and inform the charging policy debate within the NRA. It was envisaged that the paper would be used within the NRA to provide a useful reference on the economic principles underlying the charging policy debate.

Whilst the focus of the paper is on economic principles, where relevant we have indicated the significance of practical considerations. Apart from this introduction, the report comprises six chapters, as follows:

Chapter 2 Institutional Framework

The legislative and institutional constraints on NRA charging policy are considered. The NRA must comply with both EC and UK legislation. The approaches based on water quality objectives and standards (WQOs and WQSs) and on uniform emission standards (UESs) are contrasted. A major constraint imposed on the NRA by the Water Act (1989) is that the NRA may only raise income from charges for discharges and abstractions sufficient to cover its administrative costs.

Chapter 3 Setting Environmental Policy Objectives

This chapter introduces the basic concepts of environmental economics. The cost-benefit approach to regulation is discussed. Under this approach the sum of damage costs and abatement costs are minimised.

Chapter 4 Selecting Regulatory Instruments

The criteria for assessing regulatory instruments are discussed in this chapter. The key criteria are:

- effectiveness in achieving WQSs;
- minimising abatement and regulatory costs;
- revenue implications.

Chapter 5 Possible Regulatory Instruments

This chapter assesses possible regulatory instruments against the criteria set out in the previous chapter.

Chapter 6 Possible New Style Charging Schemes for Abstractions and Discharges

Recommendations are made for future NRA charging schemes.

Chapter 7 Uses of Excess Revenue and Other Issues

This chapter assesses the possible uses of revenue in excess of NRA's administration costs raised from incentive based charges. The issues of small user exemptions and application charges are also considered.

2. INSTITUTIONAL FRAMEWORK

This chapter considers the institutional framework within which the NRA must regulate the use of water resources. It focuses on three issues:

- UK and EC environmental legislation;
- existing licence and consent system;
- constraints on charges for abstractions and discharges.

2.1 Environmental legislation

One of the NRA's major roles is to implement UK and EC legislation relating to the water environment. Broadly speaking EC environmental legislation has favoured uniform emission standards, whilst UK legislation has favoured water quality standards. This section seeks to examine these two different approaches by considering the EC Urban Waste Water Directive and the provisions of the Water Act (1989). We recognise that the precise relationship between EC and UK approaches to environmental legislation is complex. However, the purpose of this section is to explain the economically relevant aspects of the two approaches to environmental legislation. No attempt is made to present a detailed review of environmental legislation pertaining to the water environment in the UK. In the interests of clarity the discussion therefore presents a somewhat simplified view of the relationship between EC and UK environmental legislation.

2.1.1 Uniform emission standards approach

EC legislation has favoured an approach based on uniform emission standards (UES). The UES approach to environmental standards emphasises the importance of establishing certain minimum levels of pollution control at the pollution source.

An example of the UES approach is the EC Urban Waste Water Treatment Directive which specifies minimum treatment and quality levels of municipal waste water. Under the Directive emissions of waste water from plants of a reasonable size must treat sewage to either secondary or the more stringent tertiary treatment levels prior to discharge.

The key feature of this approach is that little or no regard is given to variations in the ability of the environment to absorb discharged wastes. As a result, it has been argued that the standards established in the Urban Waste Water Treatment Directive are too stringent for the UK since they do not allow for the fact that UK rivers are generally shorter and faster-flowing than continental rivers and are therefore able to absorb higher effluent loads without severe reductions in river quality. This criticism has led to a heated debate in the UK over the high cost of complying with the Directive. The Directive does take into account regional factors in a limited way by distinguishing between "sensitive zones" where additional tertiary treatment is required, and "less sensitive zones" where only primary treatment is required.

2.1.2 Water Quality Standards approach

The Water Act (1989) established the central role of Water Quality Objectives (WQOs) and Water Quality Standards (WQSs) in UK environmental legislation for controlled waters. WQOs are statements of environmental objectives for such waters, and WQSs are the expression of the conditions that must be met to secure these objectives. For example, a WQS might set a numerical limit on the concentration of a particular contaminant in river water.

The WQS approach is explicitly aimed at meeting particular water quality levels. Under this approach the permissible level of discharges will vary according to the assimilative capacity of the receiving waters. In this respect the WQS approach is quite different to the UES approach because it is designed to reflect spatial and temporal variations in the impact of pollution on water resources.

2.1.3 The relationship between UESs and WQSs

The minimum standards established in EC Directives have legal priority over WQSs and must be enforced. However, WQSs can be set which imply a level of control greater than the minimum required under EC law. This is illustrated in the following example.

Consider a WQS which specifies the minimum permissible concentration of dissolved oxygen in rivers. Two situations can be distinguished with reference to the example of a sewage works discharging to a river. If the river has a large assimilative capacity for BOD discharges, the WQS might imply a less stringent level of control than is required for compliance with the EC Urban Waste Water Treatment Directive. In this case the sewage works must comply with the EC Directive. On the other hand, if the river has a low assimilative capacity for BOD discharges, the WQS will imply a more stringent level of control than the EC Directive. The circumstances under which a WQS should be set to achieve a tighter level of control than the minimum required under EC law are considered in the next chapter.

2.2 Existing licence and consent control system

The Water Act (1989) transferred the former regional Water Authorities' pollution control function to the NRA. The NRA inherited from the Water Authorities a control system for abstractions based on licences and charges, and for discharges based solely on consents. There are a number of features of the existing consent and licence systems that are important as they determine the starting point of any attempt by the NRA to improve the use of water resources. The key features are considered below (for a more detailed summary of the NRA's existing charging schemes see Appendix 1).

Over-committed abstraction capacity

In some regions the volume of abstraction permitted under existing abstraction licences greatly exceeds the available raw water capacity. This leaves open the risk of significant environmental damage occurring from over-abstraction. The problem is compounded by the view that if a licence holder remains within its licence conditions it is not liable for any damage caused by its actions.

Discharge register

The discharge register may include a number of lapsed consents. These will be identified during the current discharge charging scheme validation.

Licences and consents not fully integrated

In some controlled waters the interaction between licensed abstractions and consented discharges may be important for water quality. For example, if abstractions cause a significant reduction in river flow there may be inadequate dilution for effluent discharges. A large number of abstraction licences take this type of interaction into account by including conditions relating to minimum river flow (MRF) values to ensure adequate dilution for effluent. However, licences and consents are not fully integrated in general. We discuss the theoretical and practical aspects of this issue in section 3.1.

2.3 Constraints on charges for discharges and abstractions

The Water Act (1989) effectively imposes two constraints on the use by the NRA of charges for discharges and abstractions. These are:

- Revenue constraint
- No undue discrimination constraint

The revenue raised by the NRA from charges for discharges and abstractions can only recover the costs of administrating the schemes. The key issue is thus the definition of administration costs.

In the case of discharges administrative costs include the costs of sampling, inspection, and laboratory analysis, plus the costs of administration. In the case of abstractions the NRA can recover the total cost of carrying out the water resources function through the administration charge. An important implication of this is that the administration charge can be used to recover costs incurred in developing water resources which are debited to the Water Resources Account.

The Water Act (1989) requires that the charges for discharges and abstractions should not lead to undue discrimination. Whilst there are a number of alternative concepts of equity, the polluter pays principle indicates that charging discharges and abstractions in relation to their impact on the environment is equitable.

3. SETTING ENVIRONMENTAL POLICY OBJECTIVES

This chapter explains the basic concepts of environmental economics, and is fundamental to the later assessment of alternative regulatory instruments. The key ideas are developed using a stylised example in which the water quality of a river is reduced by the actions of a single firm. For the purpose of our example the firm is considered to be a discharger. However, the discussion is equally applicable to an abstractor. This example is used to illustrate the costs and benefits that arise from controlled waters, and to explain how these can be used in a cost-benefit analysis to provide an economic basis for environmental policy objectives.

3.1 Abstractions and discharges: a unified framework

In this chapter we treat abstractions and discharges within a unified framework. There are a number of reasons for adopting this approach. Most importantly, in economic terms abstractions and discharges are analogous in that they reduce the available capacity of receiving waters to support abstraction or assimilate discharges. Adopting a unified framework thus facilitates a logical and concise presentation of the relevant economic principles. A second reason is that abstractions and discharges may be linked; for example abstraction from a water course may reduce its assimilative capacity for discharged effluent. This would imply that the ideal policy is to integrate the setting and granting of abstraction licences and discharge consents.

However, we recognise that there could be important practical differences between abstractions and discharges that make full integration infeasible. In particular, the interconnection between abstractions and discharges may be complex. Further, there may be institutional factors concerning the division of responsibilities for the regulation of abstractions and discharges within the NRA that argue against full integration. The key point, notwithstanding these difficulties, is that there should be some degree of coordination in the issuing of abstraction licences and discharge consents for a given receiving water since they may be competing for the same environmental capacity. This is likely to be most important when abstractions and discharges occur close to one another.

3.2 Abatement costs

The firm can control its discharge load in a number of ways. For example, it can either reduce its annual production or improve the quality of its discharges through treatment. However, the firm's costs will increase as a result of such discharge control measures. These costs of discharge control, referred to as abatement costs, may be significant, particularly if the firm has to invest in expensive purification technology.

The relationship between the firm's abatement costs and the discharge load is shown by the AbC curve in Figure 3.1. In this example it is assumed that the AbC curve is smooth and slopes downwards. This reflects the assumption that small reductions in discharge load can be achieved relatively cheaply, through for example a tightening up of existing procedures, whilst large reductions may require capital investment in discharge control equipment and will therefore be expensive. Thus the firm's abatement costs fall as its discharge load increases.

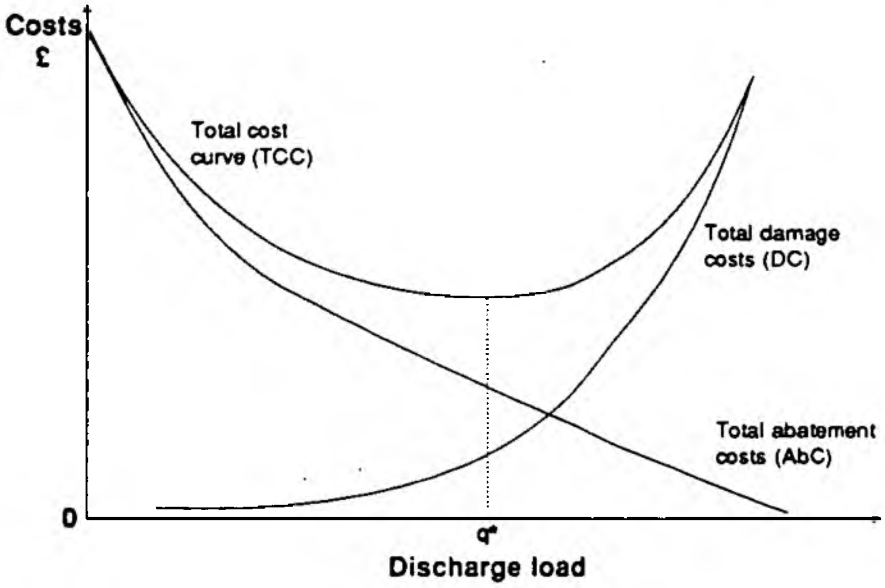

Figure 3.1 Optimal use of environmental resource - total cost method

3.3 Damage costs

If the firm's discharge load reduces the quality of the river water this may lead to a reduction in the benefit that other river users gain from activities such as water abstraction, fishing and general leisure pursuits. This may be expressed by saying that the firm imposes a cost, referred to as a damage cost, on other river users. The total damage cost imposed by the discharger on other river users is shown by the DC curve in Figure 3.1. The value of damages caused by the firm will depend on a number of factors, including:

- pollutant load in discharges;
- the firm's location on the river;
- location of other river users relative to the firm;
- hydrological state of the river;
- value placed on the river environment.

It is plausible to assume that total damage costs will rise as the discharge load increases and in this example it is assumed that the DC curve is smooth and slopes upwards.

There are two major problems in measuring damage costs. Firstly, there are theoretical difficulties involved in placing a value on water resources. Secondly, damage cost estimation techniques are undeveloped at present. The NRA has commissioned a research project (Project 253) to investigate this area. The project is at an early stage of development and no results were available at the time of preparing the report.

3.4 The optimal use of environmental resources

The ultimate aim of environmental policy is to ensure that environmental resources are used in a sustainable and efficient way. In economic terms this requires that the total cost to society of environmental resource use is minimised.

In this example the total cost to society of using the river is given by the sum of the abatement costs and damage costs. This is shown as the curve TCC in Figure 3.1. The best, or optimal level of discharge from society's point of view is q^*, which corresponds to the minimisation of total costs.

The preceding discussion was based on the use of abatement and damage costs. For our subsequent analysis it is useful to reformulate the argument in terms of incremental or marginal abatement and damage costs. These are derived from the total cost curves.

Marginal abatement costs (MAbC) are the extra costs which the firm would incur by reducing its discharge load by one unit. The firm's MAbC curve is illustrated in Figure 3.2. Like the AbC curve, the MAbC curve slopes downwards. This is because the firm can achieve a one unit reduction in its discharge load relatively cheaply if it is discharging at a high level whilst a similar reduction from a low level only be "squeezed out" by relatively expensive measures.

Marginal damage costs (MDC) are the additional costs that a one unit increase in the firm's discharge load would impose on other river users. The MDC curve is also shown in Figure 3.2[1]. As with the DC the MDC slopes upwards. This is because a one unit increase in the discharge load is more damaging if the effluent concentration is already high than if it is low.

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1 The MDC is shown as a straight line. In general the MDC may increase 'step-wise' because of thresholds for different use categories. This does not alter the analysis in any substantive way.

It can be shown mathematically that the optimal level of pollution occurs when the marginal abatement cost equals the marginal damage cost. This is illustrated in Figure 3.2 which shows that the MAbC and MDC curves intersect at the optimal level of discharge, q^*. This result is extremely important as it gives a simple condition for the optimal use of the river environment.

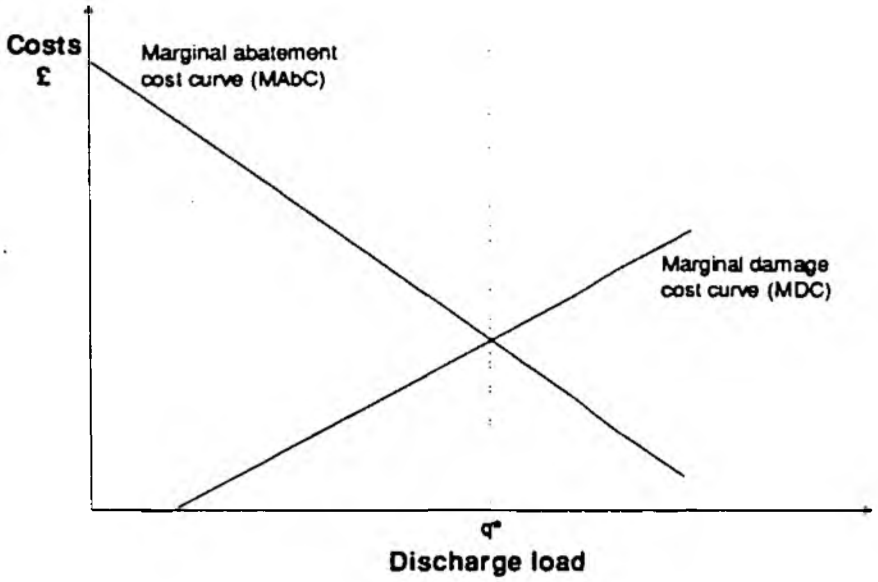

Figure 3.2 Optimal use of water resource - marginal cost method

3.5 Setting water quality standards

In chapter 2 it was noted that the UESs established in EC Directives have legal priority over WQSs. We now address the question of the relationship between UESs and WQSs. Ideally, the standard established will limit the firm's discharge load to q^*. This is shown in Figure 3.3 by the vertical line S.

UESs established in EC Directives are not based on a cost-benefit analysis, therefore it is possible that a tighter WQS may improve the use of water resources. The purpose of a cost-benefit analysis in this situation is to determine whether a WQS should be established that leads to controls over and above those under the EC Directive. This can be explained schematically by referring to Figure 3.3. If the firm's load is limited to q^* or less by an EC Directive, then a WQS tighter than this should not be set. If, however the EC Directive places a limit on the firm's load that is greater than q^* then a WQS should be set that limits the discharge load to q^*.

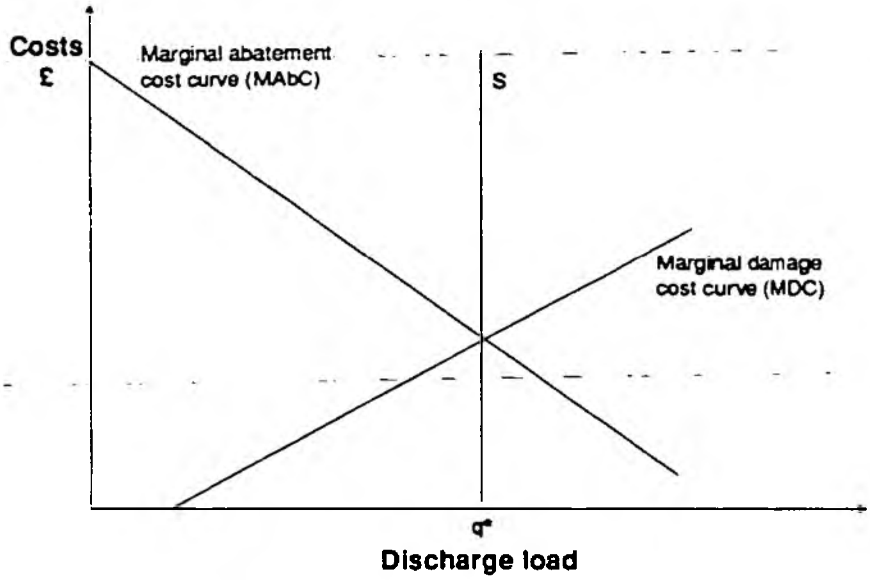

Figure 3.3 Optimal water quality standard

3.6 Limitations of the cost-benefit approach

A full cost-benefit approach as described above requires a great deal of information on damage costs and abatement costs. In practice this is unlikely to be available. Damage cost estimation poses particular difficulties, as noted in section 3.2. In addition, data on abatement costs will be expensive to collect. This represents a major obstacle to the use of cost-benefit analysis since in the absence of information on damage and abatement costs it is not possible to identify the optimal level of discharge.

The immediate objective of environmental regulation must therefore be the attainment of "acceptable" levels of water quality and discharges. Cost-benefit analysis based on the available information can form a useful input for the setting of such "acceptable" levels. In general an "acceptable" level of discharges that is set on a partial cost-benefit analysis may be too high or too low relative to the "optimal" level. For example, a WQS to the left of q^* shown in Figure 3.3 will be tighter and will lead to under-use of the river by the discharger. Conversely, a WQS to the right of q^*, will be too loose and will lead to over-use of the river by the discharger.

4. SELECTING REGULATORY INSTRUMENTS

The previous chapter explained that the immediate objective of water-related environmental regulation is to meet the standards established by EC Directives and WQSs. The NRA must therefore use one or more regulatory instruments (RIs) to ensure that the use of controlled waters is consistent with the existing UESs and WQSs.

This chapter considers five important criteria for choosing a RI. This forms the background for an assessment of the performance of the alternative RIs that are available (licences and consents, pollution charges, and marketable permits) in the next chapter.

The criteria considered are:

- how effective is the RI in meeting environmental standards;
- does the RI limit the total abatement cost to polluters of meeting standards;
- does the RI entail large administrative costs;
- does the RI raise excessive revenue;
- is the RI equitable.

These are considered in detail below.

4.1 Effectiveness in meeting environmental standards

The NRA requires a regulatory instrument that enables it to effectively meet the WQSs and UESs that are set. This means that the instrument must have a relatively certain and predictable effect on dischargers and abstractors. In addition, the regulatory instrument must allow the NRA to prevent serious environmental damage in unforseen circumstances, such as after an accidental discharge.

4.2 Minimising abatement costs

If WQSs and EC Directives are to be met it is likely that the total abatement costs of dischargers and abstractors will be very large. An acceptable RI will limit the magnitude of total abatement costs by encouraging firms that can improve water quality most cost-effectively to undertake abatement measures. This section explains the conditions which must be met if the total abatement costs involved in meeting a WQS are to be minimised. Note that no attempt is made in this section to indicate how a RI could ensure that these conditions are met.

4.2.1 The basic case

The argument is developed using an extended version of the stylised example used in chapter 3. In this example there are two firms, A and B, located on a river, and they both emit a discharge that reduces the level of dissolved oxygen (DO) in the river. The WQS specifies the minimum permissible concentration of dissolved oxygen in the river. We assume that there is a "hot spot" downstream of both firms where DO is lower than at other points on the river, and that if the WQS is met at the "hot spot" then it will be met at all other points on the river. This simplifies the explanation as it allows us to focus on the problem of minimising the total abatement cost of meeting the WQS at the "hot spot" alone.

In chapter 3 we noted that the effect of a given level of discharges on water quality depends on a number of factors, including the type of discharge, the location of the discharger, and hydrological conditions. We assume initially that A and B are located close to one another and emit discharges of a similar quality. This implies that the discharges from A and B have the same impact on DO at the "hot spot", and that the DO concentration at the "hot spot" depends only on the total level of discharges emitted by both A and B. Suppose that to meet the WQS at the "hot spot" the combined discharges of A and B must not exceed 100 units per day. It is clear that the WQS can be met in a number of ways. For example, both firms could discharge 50 units, or A could discharge 20 units and B 80 units. However, the total abatement cost of meeting the WQS will in general differ between the alternative discharge patterns, and the problem is how to determine the discharge pattern which meets the WQS at the lowest abatement costs.

This situation is illustrated in Figure 4.1 which shows A's abatement costs (AbC_A) B's abatement costs (AbC_B), and the sum of these (TAbC). The horizontal axis shows how a total of 100 units of discharges is distributed between A and B. Thus, at the extreme left of the horizontal axis A discharges 100 units and B discharges 0 units. Conversely, at the extreme right A discharges 0 units and B discharges 100 units. At any point between these extremes the sum of A's and B's discharges is 100.

The TAbC curve gives the total abatement cost incurred by both A and B of meeting the WQS for all possible distributions of the 100 units of discharges between A and B. In Figure 4.1 the TAbC curve is U-shaped and the total abatement costs of meeting the WQS are minimised when A discharges 60 units and B 40 units. This may be compared with a UES approach which would limit the discharges of both A and B to 50 units and would lead to higher total abatement costs. Intuitively, this is because the reduction in A's abatement costs from increasing its discharges from 50 to 60 units exceeds the increase in B's abatement costs from reducing its discharges from 50 to 40 units, and hence the total abatement cost is lower with the 60-40 discharge pattern.

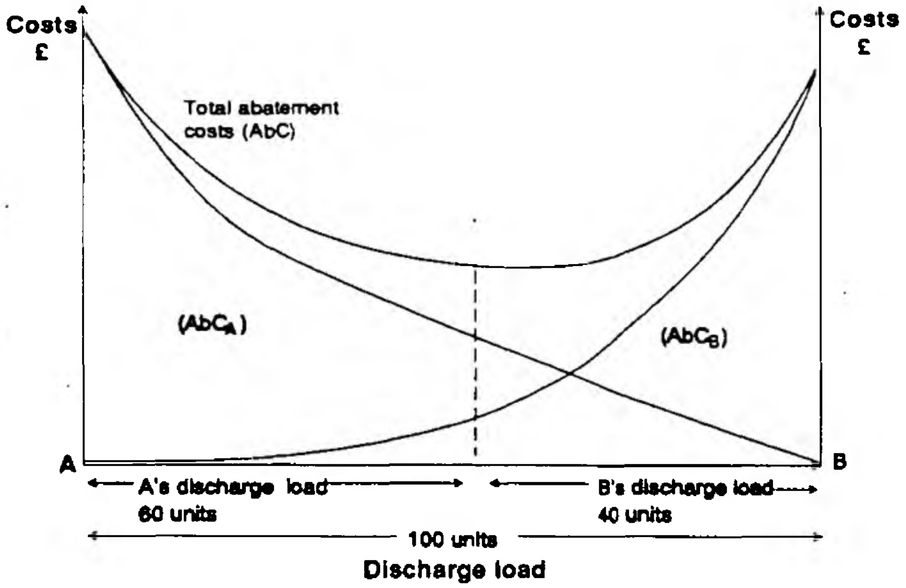

Figure 4.1 Minimising abatement costs

It can be shown mathematically that if total abatement costs of meeting a WQS are to be minimised the marginal abatement costs of A and B must be equal. This condition may be stated as:

(1) $MAbC_A = MAbC_B$

The result expressed in equation (1) was derived from a highly simplified example. We now consider briefly how the result is modified by some of the complexities that may occur in reality.

4.2.2 Allowing for different effects on water quality

The first complication we introduce is to allow for discharges from A and B to have different effects on DO at the "hot spot". For example, if A is located upstream of B, natural dispersion will result in A's discharge load having a smaller effect on DO at the "hot spot" than B's. This implies that the effect of a given level of total discharges depends on how it is distributed between A and B. When the source of the discharge load matters in this way it is not possible to translate the WQS into a simple limit on the total discharge load.

The pattern of discharges that minimises the total abatement cost of meeting the WQS must therefore take into account not only the relative abatement costs of A and B, but also the relative effects of their discharges on DO at the "hot spot".

For example, if the cost of reducing discharges is similar for A and B the WQS would be met most cheaply if firm B reduces its discharge load by more than firm A. This is because a smaller reduction in B's discharge load causes a larger improvement in water quality than the same reduction by A.

The condition for minimising the total abatement costs of meeting the WQS in this situation is:

(2) $MAbC_A / Q_A = MAbC_B / Q_B$

Where Q_A and Q_B give the impact on water quality at the "hot spot" of an increase in A's and B's discharge load respectively. The key point is that (2) is a modification of condition (1) which takes into account the difference in the impact of discharges from A and B on water quality.

4.2.3 Allowing for dynamic effects

The analysis presented to date is essentially static, and strictly only applies to a steady state situation. This is unrealistic in a number of ways. At a basic level the behaviour of pollutants in the river is determined by physical processes which are inherently dynamic. In addition there may be significant variations over time in hydrological conditions, such as the river's flow and temperature, and in the type and quantity of effluent affecting the river.

Variations in hydrological conditions mean that the effect of a given discharge load on water quality will vary over time. For example, when the river flow is low the discharge load will be less diluted than when the flow is high and may have a more damaging effect on water quality. One implication of this is that the discharge load that is consistent with a given WQS may vary over time.

The quality and load of discharges into the river may vary over time for a number of reasons. For example, point source discharges will vary because of variations in both the activities of firms and in the quality of the inputs they use. For example, the thermal pollution from a power station's cooling water will depend on the electricity demand being met by that power station. A further major source of variation is from diffuse source discharges. The issue of diffuse source discharges will be discussed in more detail in chapter 5. Here we simply note that they arise as a result of factors such as agricultural run-off and can have a major impact on water quality.

The effect of these dynamic factors on the cost-minimising condition expressed in equation (2) is that the polluters' MACs and their impacts on water quality vary over time. The cost-minimising condition then becomes that equation (2) must hold at all points in time.

4.2.4 Many firms and pollutants

The analysis is more complex when there are many firms emitting a wide range of pollutants and there are several WQSs to be met. However, it is not substantively changed. In particular, the key insight that the burden of abatement should be borne by firms that can improve water quality most cost-effectively remains valid.

4.3 Administrative costs

An acceptable RI should not require excessively high administrative costs in order to be effective. The determinant of administrative costs that we focus on here is the amount of information that the NRA must collect to make the RI effective. Equation (2) suggests that knowledge of firms' abatement costs is required if WQSs are to be met cost effectively. Firms will generally have good information about their own abatement costs, and the NRA can probably only obtain this information by undertaking expensive research. Thus a key feature of an acceptable RI is that it provides firms with incentives to act on their knowledge of their abatement costs. In this way, the RI will allow WQSs to be met at a low total abatement cost without entailing excessive administrative costs.

4.4 Revenue implications

An acceptable RI must enable the NRA to recover its administrative costs with certainty. Under the existing revenue constraint on the NRA it is also important to consider whether the RI will raise revenue in excess of the cost-recovery level.

4.5 Equity

It is important that any new RI is regarded as equitable. In particular the NRA is constrained by the requirement that no undue preference or discrimination is shown between dischargers or abstractors.

The MBIs considered in chapter 5 involve paying in relation to the environmental costs imposed. This is equitable under the "Polluter Pays Principle".

5. POSSIBLE CONTROL SYSTEMS

This chapter considers the alternative regulatory instruments which could be used to ensure that environmental targets for water quality are met. The RIs that we consider are:

- quantity controls on discharges and abstractions;
- discharge and abstraction charges;
- quantity controls and charges;
- tradeable pollution permits.

These RIs are described and assessed against the criteria set out in chapter 4. The main discussion of RIs in this chapter applies to point source discharge and abstractions. Diffuse source pollution raises additional problems and is discussed in the concluding section of this chapter.

The main focus of this chapter is on market-based instruments (MBIs), that is charges and tradeable permits. However, we commence with an assessment of quantity controls since this forms the background to considering the combined use of charges with quantity controls.

5.1 Quantity controls

The existing consent and license system exemplifies the approach of direct quantity control over discharges and abstractions. Under this system the NRA specifies individual limits for each discharge permit and abstraction license holder.

5.1.1 Effectiveness

The main appeal of quantity controls is that they give the NRA direct control over the maximum levels of discharges and abstractions. Under such a regulatory system, quantity limits must be set for individual abstractors and dischargers in order to achieve water quality standards.

In terms of the NRA's existing system, the allocation of consents and licences should be consistent with water quality standards. However, there are problems with the present system since existing consents and licences are in some cases too large to meet water quality standards. Correcting these problems would require either reallocation or withdrawal of these consents. Alternatively charges may be used as an incentive mechanism in addition to the existing consents.

A detailed pollution model is required to implement a quantity control system in order to translate water quality standards into limits on abstractions and discharges. This requirement is not unique to quantity controls; it arises with all regulatory instruments. The regulatory authority must be able to estimate the impact of abstractors' and dischargers' actions on water quality if water quality standards are to be achieved.

Limiting discharges and abstractions does not guarantee a fixed level of water quality. The state of the receiving water, and thus its capacity to assimilate effluent, is likely to vary over time, for example due to seasonal flow variations. Ideally, quantity controls should take account of variations in the receiving water, for example by setting stricter limits during the summer. Clearly there are limits to the complexity of controls. In practice there are many factors that determine the assimilative capacity of the receiving water which cannot be taken into account by quantity controls.

5.1.2 Abatement costs and information requirements

In order to achieve a target water quality level the information required by the NRA is a pollution model which can predict the effects of abstractions and discharges on water quality. However, such an approach does not necessarily implement the target water quality level at least cost since in general there will be many different ways of sharing the burden of abatement amongst firms. Discharges and abstraction must satisfy condition (2) in chapter 4 in order to minimise total abatement costs. This requires information on both abatement costs of individual dischargers and abstractors as well as the impact of the respective firms on water quality. Trying to set quantity limits to minimise total abatement costs would place a large information burden on the NRA.

5.1.3 Revenue generated

Quantity controls could easily satisfy the current revenue constraint imposed by the Water Act on the NRA. It is possible to set charges such that administrative costs are recouped without generating excess revenue, as under the present discharge charging scheme.

5.2 Discharge and abstraction charges

Discharge and abstraction charges are an example of a market-based pollution control instrument. Under such a pollution charge system the NRA would attempt to meet the target water quality by levying a charge on abstractors and dischargers. This charge would provide an incentive for firms to abate their discharges or reduce abstractions.

For example, if one quality standard places a minimum allowable value on the dissolved oxygen concentration in a river then the regulatory body could levy a charge on firms that depends on the BOD of their effluent. Each firm then has a financial incentive to reduce the BOD of its discharge, either by reducing the discharge load, or by improving the discharge quality. By setting the charge at a high enough level the regulatory body can ensure that the dissolved oxygen standard can be met. In principle, a separate charge would be required for each pollutant that affects the meeting of the WQS.

5.2.1 Effectiveness

The effectiveness of charges in meeting water quality standards is influenced by two forms of uncertainty. The first form is that the effects of abstractions and discharges on water quality are uncertain. This uncertainty also affects the success of quantity controls. The second form of uncertainty is that the regulator does not have complete information about the effect of charges on the actions of dischargers and abstractors. This form of uncertainty does not affect quantity controls. Uncertainty concerning the likely responses of firms to charges is a key problem. It will form an important argument in favour of combined charging and quantity control systems in section 5.3.

5.2.2 Abatement costs and information requirements

As with quality controls, the NRA must have a pollution model that can predict the effects of abstractions and discharges on water quality. In addition, in order to determine the level of charges required to achieve a WQS the NRA would require detailed information on the effects of charges on the actions of dischargers and abstractors. This requires knowledge of their abatement costs and is a considerable information burden on the NRA. However, under certain conditions the use of pollution charges can minimise the total abatement cost of meeting water quality standards without any further information.

The cost minimising property is a very attractive feature of the charging approach. However, this only holds when charges for individual dischargers or abstractors are related to the effect of a discharge or abstraction on water quality. Since the effect of a given discharge or abstraction on water quality usually varies markedly with its location, it follows that an equal charge per unit for a given effluent regardless of its source will not generally minimise the cost of achieving a given improvement in water quality. For example, given two firms with identical abatement costs but different effects on water quality, the firm with greatest impact on water quality should abate most if total abatament costs are to be minimised. Thus, to minimise the costs of meeting a given quality standard charges must be differentiated so that firms which have a big impact on water quality are charged at a higher rate.

The determination of charges to ensure minimisation of total abatement costs requires both the level and structure of charges to be determined. The charge for each discharger or abstractor should be set in proportion to the marginal impact of that discharger or abstractor on water quality. This will promote abatement cost minimisation as firms have the correct incentives to choose discharges and abstractions which satisfy condition (2) of chapter 4. The level of charges must then be set so that actual water quality is equal to target water quality. Determination of the level of charges requires information on how charges will affect dischargers and abstractors. Thus, knowledge of abatement costs is required to set the level of charges, though the structure of charges (ie the relative prices charged to different firms) depends on their relative impact on water quality. The mathematical details of this argument are given in Appendix 4.

If information on abatement costs cannot easily be obtained the NRA can search for the correct price level by making a series of price adjustments. If water quality is too low, charges are raised until the WQS is achieved, whereas if water quality is above the WQS, charges could be lowered. A possible problem with this approach is that if charges are subject to continuous revision then they fail to provide long term incentives to reduce pollution. One way around this problem would be to implement a system of "creeping charges". Under such a scheme the regulatory body would announce that charges would be raised annually at a certain percentage rate in real terms. This increase would occur until water quality objectives were met. Such a scheme would offer good long term incentives for abatement. The slow increase in charges would operate as a transition period. However, water quality could be seriously damaged in the short term if the charging level was initially too low.

A key point is that a trade-off exists between the complexity of the charging scheme and the costs of meeting water quality standards. In principle a charge which accurately reflects the impact of an individual polluter on water quality can minimise the costs of meeting water quality standards. The main problem is to find a proxy for the impact of discharges and abstractions on water quality on which to base charges. If a suitable proxy can be found some of the cost-minimising benefits of charges can be retained. Ideally we would wish to take account of such factors as: the quantity of abstractions and emissions; the location of the abstractor or discharger; the type of receiving water and season. Where load of discharges (or abstractions) is not a good proxy for effects on water quality we may distinguish between load-based charging and damage-based charging systems. We consider some possible approaches to constructing charging systems in chapter 6. An important benefit of charging schemes is that there are stronger incentives for adopting abatement cost reducing innovations under charges than under quantity controls. The reason for this is that under a charging scheme a firm improving its abatement technology not only reduces its abatement costs but also reduces its discharges and hence its discharge charge bill. Thus charges may be more efficient than direct controls in improving water quality in the long term. This conclusion also holds true for tradeable permit systems.

5.2.3 Revenue generated

It is likely that charges for discharges and abstractions will generate revenue in excess of administrative costs if they are to provide effective incentives. This is because to be effective, the level of charges must be comparable with firms' abatement costs.

One solution to the problem of the revenue constraint is that of granting "free allowances". The principle behind this is to give abstractors and dischargers a free allowance of abstractions or discharges and then to charge only for abstractions or discharges in excess of the free allowance. Revenue is lower under this scheme since it is raised only on excess usage.

The price charged for excess usage should be the same as the price which would be set under the simpler charging scheme in which a volumetric charge is levied on the entire usage. If this charging scheme is to have proper incentive effects it is most important that once the free allowance is exhausted charges are levied only on excess usage and not on total usage.

Although straightforward in principle, this charging scheme would require the NRA to forecast firms' responses to charges in order to determine the size of the free allowances. At given charges firms will choose particular discharge or abstraction levels determined by their abatement costs. Free allowances must be chosen for each firm which are below these levels, otherwise they would not use up their free allowances and there would be no incentive to reduce emissions. Determining free allowances places a considerable information burden on the NRA. The tighter the revenue constraint on the NRA, the heavier this burden will become. The smaller the revenue the NRA is allowed to collect then the closer free allowances must be to the actual discharge and abstraction levels which the firms will choose. This would require the NRA to forecast the responses of firms to charges with greater accuracy.

5.3 Combining quantity constraints and pollution charges

We have already seen that either quantity constraints or charges on discharges and abstractions may be used as policy tools to achieve target water quality standards. We now consider systems combining quantity constraints and charges.

It is important to consider combined systems since the NRA must work within the constraint of previously issued licences and consents. These form effective quantity constraints on abstractions and emissions. If the NRA introduces charges as a policy instrument it would be in addition to these existing quantity constraints.

There may be sound economic reasons for placing comparatively slack quantity constraints on abstractors and dischargers and using charges in order to achieve tighter control. A pure charging system without quantity constraints requires the regulator to have information about firms' likely actions under various hypothetical charging levels. This information is needed to implement a water quality standard by choosing an appropriate charge level. Clearly this information is only partially available to a regulator, if at all. If charges were set too low, the target water quality level would not be achieved. Placing quantity constraints on discharges or abstractions would limit the worst case outcome if the regulator misjudged the charge level. Quantity controls provide a safety net if regulators have imperfect information about abatement costs and incorrectly set the charge level. By combining charges and quantity controls the beneficial incentive effects of charges can be maintained whilst minimising the risks resulting from the regulatory authority having imperfect information about abatement costs.

Charges have an allocative role in situations where the NRA wishes to achieve a water quality level superior to that resulting from the existing quantity controls. This may occur if WQSs are not being met currently, or if new discharges need to be accommodated. However, there is no such role in situations where existing discharge limits are extremely tight. For example, it has been argued that the EC Urban Waste Water Directive is inappropriate for some UK rivers, since the emission controls are too strict; slackening the emission controls would save more in abatement costs than it would lose in damage costs. If this were the case there would be no allocative role for incentive based charging, since water quality would already be above its socially optimal level.

5.4 Tradeable pollution permits

Tradeable permits are a market-based pollution control instrument. They have been discussed extensively in the economics literature and have been used in the USA. Tradeable permits are potentially attractive as a means of reducing the cost of achieving environmental quality standards, such as WQSs, without placing a heavy information burden on the regulatory authority.

The central idea of tradeable permits is that of firms owning property rights in the form of permits for the use of environmental resources. The role of the regulator is to define the property rights for a particular aspect of the environment and issue appropriate permits. For example, the regulator might create a limited number of permits for the discharge of a specified pollutant into a river: the total number of permits would determine the total level of pollution. Each permit would authorise a given discharge load, and firms would be required to hold permits covering their level of discharges. Violators would be liable to a fine if they exceeded the discharges allowed by their permits. These permits could be traded between dischargers. The permit market would determine a price for permits in the same way as a share price is established in equity markets.

There are three main types of tradeable permit systems. They are able to deal equally well with dischargers and abstractors. The three systems are outlined below for the case of a number of firms discharging into a river:

Ambient Permit System (APS)

APS requires that the setting up of a number of receptor points at which water quality is continuously measured. For each receptor point, permits are issued which entitle the holder to cause a certain reduction in water quality at that point. Permits for individual receptors points may be traded. A particular discharger will generally find that he must hold a portfolio of permits, since his discharges will typically affect more than one receptor point.

Emissions Permit System (EPS)

A water resource is divided into zones. Within each zone permits are issued entitling the holder to discharge a certain quantity of effluent into that zone. Permits may be traded within zones. EPS ignores spatial differences between firms within zones. EPS is in some ways similar to the existing system of granting consents and licences; the difference is that under EPS these may be traded.

Pollution-offset system (POS)

POS combines elements of APS and EPS. Permits are defined in terms of emissions as with EPS. However, the trading of permits between sectors is allowed provided that water quality standards at each of the receptor points are not violated.

In theory, the ambient permit and pollution offset systems offer a method of unifying abstractors and dischargers in a single permit system that is able to account for the interrelationships between the two groups. An emission permit system would be inadequate since abstractors and dischargers have different effects on water quality. An integrated ambient permit system would involve setting up a number of receptor points at which water quality measurements would be taken. Generally there would be one measurement for each type of pollutant. Permits allowing the holder to cause a certain reduction in water quality would then be issued for each water quality measure at each receptor point. Abstractors would need to hold a considerable portfolio of permits, since they would influence a number of water quality measures.

5.4.1 Effectiveness

The main benefit of tradeable permit systems is that they provide a market based instrument which can directly regulate dischargers and abstractors. In the next section we examine how they can minimise total abatement costs. They avoid the difficulty which arises with charging schemes of forecasting the likely actions of dischargers and abstractors under various charge levels. Tradeable permits define the acceptable level of environmental damage and allow the permit market to determine a price for the right to cause this damage.

A second benefit of tradeable permits is that they allow the regulatory authority to implement a change in WQSs in a straightforward manner by adjusting the number of permits. For example, a tighter WQS may be implemented by the regulator "buying-back" permits to reduce the number of permits held by firms. A phased buy-back programme can provide a way of achieving an improvement in water quality over time that encourages firms to adopt cost effective abatement methods.

A problem with tradeable permit systems for abstractions and discharges is that of "thin markets" in permits. If there are few holders of permits then they may be infrequently traded. In addition, if the permit market is dominated by one or few firms they may use this dominant position to their advantage since they are able to influence the permit price. If this occurs tradeable permits will not minimise total abatement costs.

Another important problem is that of pollution "hot spots". If permits become concentrated in the hands of a dominant firm, then highly localised pollution may result. This is particularly a problem for the emissions permit system. The ambient permit and pollution offset systems attempt to overcome the hot spot problem by trying to control water quality at a number of receptor points. In particular, these two systems can take account of differences between abstractors and dischargers in their effects on water quality. However, there is still a danger of hot spots developing in areas between the receptor points.

It is important to note that there is a fundamental conflict between the thin market and hot spot problems. If permit markets are sufficiently localised to prevent hot spots, they are likely to contain few firms and so few trades will occur. On the other hand if permit markets have many participants so that thin market problems are avoided, there is little control of localised pollution levels and hot spots may occur.

The hot spots and thin markets problems limit the application of tradeable permits to regulate the use of controlled waters. There are many situations in which there are a small number of dischargers or abstractors using a body of water; for example water and sewage companies are often dominant users. However, there may be some circumstances in which these problems can be overcome. Tradeable permits are applicable to situations in which there are a large number of small dischargers and abstractors in a small area. The greater the degree of mixing of the receiving water the less severe are hot spot problems.

5.4.2 Abatement costs and information requirements

The principal attraction of tradeable permits is that they provide a mechanism for minimising the total abatement costs of meeting a given quality standard. This occurs because firms that have high abatement costs will be willing to avoid these costs by paying more for permits. Conversely, firms that have low abatement costs will be willing to sell permits cheaply. Therefore, there is an incentive for low abatement cost firms to sell permits to high abatement cost firms. As with quantity controls and charges, the NRA must have a pollution model to use tradeable permits. Implementation of tradeable permits requires the modelling of the relationship between discharges, abstractions and water quality so that the impact of individual dischargers and abstractors on water quality at receptor points can be determined.

However, the main advantage of tradeable permits over charges and quantity controls is that the regulatory authority needs comparatively little economic information in order to minimise total abatement costs. In particular, the regulator needs no information on the abatement costs of individual firms. The information burden has been transferred from the regulator to firms, who must determine whether there were any mutually beneficial trade of permits which could be made.

The regulator does have a considerable monitoring role, however. Implementation of tradeable permits would entail monitoring of the discharges and abstractions of all permit holders to ensure that they did not violate the terms of their permits.

5.4.3 Revenue generated

There are a number of possible mechanisms for initially allocating permits. The permits could be either distributed freely or auctioned to the highest bidder. It is therefore possible to operate tradeable permit systems within the existing revenue constraint on the NRA. Permits could be initially allocated free of charge, and then an annual charge levied on permit holders to cover administrative costs. If in the future the revenue constraint is lifted from the NRA it would be possible to raise revenue by auctioning permits.

5.5 Controlling diffuse sources

Diffuse sources of pollution are a particular problem for charging systems. It may be exceedingly difficult to identify the contributions being made by particular sources of diffuse pollution and to control these.

However, it is worth distinguishing between discharges which originate from a single point source but which enter controlled water in a diffuse manner, and truly diffuse sources. An example of the former would be a waste storage site causing leaching of pollutants into ground water. Although the effluent enters water resources via groundwater, it is possible to identify the damage costs imposed on other water users and so to set appropriate charges for the waste site. Wherever they can be identified diffuse sources should be charged according to the effect on water quality on the same principles as for point sources.

Agrochemicals and animal waste are examples of truly diffuse sources and as such cannot be controlled directly. Instead an indirect approach is needed, in which control is exercised on the activities which lead to discharges. An example of an indirect control method would be an agrochemical tax, which would include in the price the environmental costs of chemical usage.

This would provide an incentive to reduce chemical use and hence reduce diffuse discharges. Indirect control methods would require legislation to implement and also coordination with other bodies such as the Ministry of Agriculture, Fisheries and Food (MAFF).

6. POSSIBLE NEW-STYLE CHARGING SCHEMES FOR DISCHARGES AND ABSTRACTIONS

This chapter considers whether tradeable permits or charges could be used by the NRA to regulate the use of controlled waters. We briefly examine the case for tradeable permits and conclude that they cannot form the basis for a national system of pollution control. The use of charges in combination with the existing system of consents and licences is then considered. We conclude that charges can form the basis for a national system which provides dischargers and abstractors with effective incentives to reduce their impact on controlled waters. We outline a possible methodology for setting charges, and propose alternative charging schemes for the situations in which the NRA's revenue generated from charging is constrained to cover administrative costs and that in which it is unconstrained.

6.1 Tradeable Permits

There are strong theoretical arguments for the use of tradeable permits for both discharges and abstractions. In principle, tradeable permit systems can be designed which can minimise the abatement costs of meeting WQSs without involving high regulatory costs. Further, the revenue raised under a tradeable permit system can easily be restricted to cover the NRA's administrative costs without generating excess revenue.

Unfortunately, the potential benefits of tradeable permit systems will only be realised under highly restrictive conditions. In chapter 5 we explained that permit trading may be limited either by the presence of a dominant firm in the permit market, or if there are only a small number of permit holders. If this occurs it is unlikely that total abatement costs will be minimised. The case study of Fox River, Wisconsin in Appendix 3 considers the difficulties involved in applying tradeable permits to water quality in practice.

In our opinion effective tradeable permit markets cannot be established for all receiving waters in the UK. On many water courses pollution damage is largely the result of the actions of a single large abstractor or discharger, and this would lead to severe problems of dominance in the relevant permit markets. This rules out the possibility of using tradeable permits as the basis for a nationally applied system of regulation. However, it is possible that tradeable permits could be used on a limited basis in some areas.

In addition to these theoretical criticisms, the implementation of tradeable permits will involve a significant change in the legal status of existing licences and consents if they are to be transformed into tradeable permits. In particular, the licences and consents must be altered to become transferable property rights which firms can buy and sell.

6.2 Pollution charges in combination with licences and consents

There are also good theoretical arguments for the use of charges in combination with licences and consents. In chapter 5 we argued that this can provide abstractors and dischargers with incentives to reduce the total abatement costs of achieving WQSs, both in the short-run, and in the long-run by encouraging investment in abatement technology. A further benefit is that charges can act in a corrective role if the number of issued licenses and consents for a particular body of receiving water is excessive.

Chapter 5 also set out the theoretical basis for setting charges. The key point is that abstractors and dischargers should be charged in proportion to their impact on water quality. Thus, the structure of charges depends on the relative impact of these firms on water quality. The level of charges is then set to ensure that WQSs are met. This suggests that there are two principal difficulties in applying charges:

- determining the impact of firms on water quality;
- determining the level of charges required to meet WQSs.

In the next section we outline a methodology for implementing charges.

6.2.1 Implementing pollution charges

In principle, the impact of a discharger or abstractor on water quality can be established by constructing a pollution model of the receiving waters. Ideally, this should take into account all the factors which affect the impact of a firm on water quality. This would be a highly complex and expensive exercise and is not a realistic undertaking for a large number of receiving waters. The Tees study considered in Appendix 3 illustrates the difficulty of constructing such a pollution model.

We therefore propose that the impact of a firm on water quality be represented through a simple proxy. This is constructed by assigning weights to the key determinants of the impact a firm has on water quality. These weights are summarised in an "impact matrix". There will be a separate impact matrix for each aspect of water quality for which a charge is to be levied.

The impact matrices establish the relative impacts of firms on water quality. This leaves the problem of establishing the level of charges that will meet WQSs in all receiving waters. We suggest a charging strategy which enables the NRA to "search" for the appropriate level of charges.

Impact matrix

The impact matrix summarises the relative importance of the major factors that determine the impact of a firm on water quality. It is similar in structure to the matrix of factors used in the NRA's new discharge charging scheme. The two key elements in the impact matrix are:

- the impact factors;
- the impact weights.

The impact factors are the variables which determine the impact of a polluter on water quality. These should include:

- discharge volume;
- discharge contents;
- receiving waters;
- abstraction volume;
- return volume from abstraction;
- season;
- location.

The factors should be broken down into bands, as in the NRA's discharges charging scheme. Thus the discharge volume factor includes a number of volume categories, the contents factor a list of pollutants, and the receiving waters are classified as ground waters, coastal waters, surface waters, and esturial waters.

The seasonal factor is included to reflect regular variations in the assimilative capacity of receiving waters. The simplest distinction would be between summer and winter months.

The location factor is introduced to reflect variations in the assimilative capacity of similar categories of receiving water. The simplest distinction is between different NRA regions. This approach will not capture differences between the assimilative capacities of similar categories of receiving waters within NRA regions. It is possible to overcome this by having different bands for receiving waters within NRA regions. However, this will add to the complexity of the scheme.

Each band is given an impact weight that should reflect the relative effect on water quality. For example, the discharge volume impact weight will be larger for high discharge volumes than for low discharge volumes. Similarly, pollutants that have a powerful impact on water quality will have a higher impact weight than less damaging ones. The exact relationship between the impact weights in the matrix must be determined empirically.

The total impact weight for a firm is determined by multiplying the relevant impact weights for each of the impact factors. This is analogous to the computation of the number of chargeable units in the discharge charging scheme. Table 6.1 shows the structure of the impact matrix for dissolved oxygen (DO) for a discharger, and the computation of the discharger's total impact weight.

Table 6.1 An illustrative example of the pollution charging scheme

Impact matrix for DO

Factor	Weight
content	a
volume	b
receiving water	c
location	d
season	e

Firm i's total impact weight (q^{i}_{DO}) = a x b x c x d x e

The unit charge matrix

Receiving water	DO	NH_3
1	p^{1}_{DO}	$p^{1}_{NH_3}$
2	p^{2}_{DO}	$p^{1}_{NH_3}$

Calculating firm i's charge for receiving water 1

Total charge = $(p^{1}_{DO} \times q^{1}_{DO}) + (p^{1}_{NH_3} \times q^{1}_{NH_3})$

A key point to note is that the impact weights for a given firm can be determined with reference to either its consent or license conditions, or to its actual discharges or abstractions. The first approach forms the basis of a capacity charge, whilst the second approach forms the basis of a load-based charge. We return to this below.

The impact matrix is likely to be an imperfect proxy for the "true" pollution model. The accuracy of the approach will depend both on how well the actual relationship determining the impact of firms on water quality is captured by multiplying together a number of impact weights, and on the accuracy of the estimated weights. Increasing the number of factors' and bands in the matrix is one way of improving the proxy. However, there is a trade-off between the simplicity of the scheme and the level of complexity. The main attraction of the impact matrix is that it is a simple way to capture the major variations in the impact of dischargers and abstractors on water quality.

Charging strategy

The impact matrix allows the computation of the impact of each discharger and abstractor on each aspect of water quality on which a charge is to be levied. The NRA must then determine the level of charges that will ensure that WQSs are met. In principle, a unit charge should be set independently for each aspect of water quality and each body of receiving water. The matrix of unit charges in the case where there are two aspects of water quality on which charges are to be levied (dissolved oxygen concentration, and ammonia concentration), and two bodies of receiving water is shown in Table 6.1. Each firm pays a charge for its impact on water quality that is calculated by multiplying its total impact weight by the unit price. Table 6.1 shows the computation of firm i's total charge.

The level of charges should reflect firms' abatement costs if they are to provide effective incentives for them to alter their behaviour. Since the NRA cannot obtain accurate information on abatement costs it is necessary to "search" for the effective unit price.

We suggest that the NRA adopt a charging strategy based on an "RPI+X" rule. Under this rule the NRA would set an initially low unit price and increase this by X% over and above inflation each year. The NRA should state the series of factors that will apply for a reasonable future period, for example the next 5 years. This approach will enable the NRA to determine the effective unit price in a systematic way. The main advantage of this is that firms will know in advance the future pollution charges they will face, and thus have good information on which to base investment decisions. Increasing price rules have been used with some success in Europe (see Appendix 2). In addition, the scheme automatically provides a transition period during which firms can develop alternatives to their current use of water resources.

Capacity charges and load charges

We mentioned above that firms can be charged either a capacity charge or a load charge. Load charges would require the monitoring of discharge and abstraction loads. This would necessitate either on-line metering or random sampling. Capacity charges are administratively attractive since the impact weights are based on consent conditions, and this avoids the difficulties of estimating firms' actual loads.

Under capacity charges a polluter can only alter its total pollution charge by voluntarily reducing its consent or licence conditions. This is attractive as it may allow the accommodation of new discharges or abstractions on some controlled waters. However, polluters may be unwilling to voluntarily reduce their consents or licences because this entails a loss of flexibility, and the effective unit price will then have to be higher under capacity charges than under load charges. The effectiveness of capacity charges might be increased by waiving the application charge for voluntary reductions of consent or licence conditions. The choice between capacity charges and load charges therefore depends on achieving an acceptable trade-off between the level of administrative costs and the level of pollution charges.

Integrating abstraction charges and discharge charges

The preceding discussion applies to charges for both abstractions and for discharges. An important feature of the proposed scheme is that whilst it provides a common framework for abstraction and discharge charges, it is not necessary that the charges be fully integrated.

The principal link between abstractions and discharges is through the impact matrix. In a fully integrated approach the impact coefficients for a given receiving water should be based on a pollution model that takes into account the interactions between abstractions and discharges. We noted earlier that it may be infeasible to adopt an integrated approach. If this is the case an alternative is to estimate the impact coefficients relating to discharges separately to those relating to abstractions. These can then be used to set separate unit charges for abstractions and discharges if desired.

6.3 Alternative charging schemes

In this section we consider two charging schemes based on the principles outlined above for the revenue unconstrained and constrained cases.

6.3.1 Charging scheme without revenue constraints

Tariff structure

There are two elements to the charge:

- administrative charge;
- pollution charge.

Level of charges

We suggest that the NRA's existing scheme of charges for discharges and the proposed scheme for abstractions should form the basis for this charge.

The pollution charge is a set of unit prices, one for each aspect of water quality on which a charge is to be applied. As explained in Section 6.2.1 a different set of unit prices will apply to each body of receiving water, and different prices can be set for abstractors and dischargers if required. A firm is then charged an amount for each aspect of water quality equal to its total impact weight multiplied by the unit price. The total impact weight can be computed on a capacity or a load basis as described above.

Main features of scheme

There are four notable features of this scheme:

- charges are ideally set on a sub-regional basis for each body of receiving water;
- a common framework is used for both abstractions and discharges, but full integration is not necessary;
- revenue will exceed cost recovery level;
- pollution charges reflect the effects on quality and are therefore non-discriminatory.

6.3.2 Charging scheme with revenue constraint

Revenue raised under the scheme described above will exceed administrative costs because the pollution charge supplements the administrative charge. This means that the scheme cannot be implemented without an amendment to the Water Act (1989).

There are two simple modifications to the scheme that could reduce the amount of revenue raised to the cost recovery level. First, the pollution charge could be abandoned so that the charging scheme only recovers the NRA's administrative costs. It is unlikely, however, that the level of charges will be high enough to provide firms with effective incentives to reduce their impact on water quality.

A second approach is to drop the administrative charge and levy only the pollution charges. The problem with this is that pollution charges must be set at the level that effectively meets the WQS. Now for a given WQS this level is determined by firms' abatement costs, and it is quite probable that the level of charges will therefore have to be high to meet WQSs. Thus the pollution charge alone may generate revenue in excess of administrative costs.

We present here a charging scheme based on the "free allowance" idea outlined in Section 5.2.3. that may provide effective incentives without raising excess revenue.

Tariff structure

There is only one element to the charge:

- pollution charge.

Level of charges

Once again, the pollution charge is a set of unit prices, one for each aspect of water quality on which a charge is to be applied, and different prices can be set for abstractors and dischargers if required. A different set of unit prices will apply to each body of receiving water. A polluter is then charged an amount for each aspect of water quality equal to its total impact weight multiplied by the unit price.

The key point is that firms are charged only for their abstractions or discharges in excess of some free allowance. Thus the total impact weight for a firm is computed on the basis of the excess abstraction or discharge load.

Main features of scheme

- charges are ideally set on a sub-regional basis for each body of receiving water;
- a common framework is used for both abstractions and discharges, but full integration is not necessary;
- the NRA must determine the appropriate level of free allowances for each licence or consent holder;
- pollution charges reflect the effects on quality and are therefore non-discriminatory.

7. USES OF EXCESS INCOME AND OTHER ISSUES

7.1 Uses of excess income

The imposition of charges on abstractors and dischargers would probably generate revenue in excess of the regulatory scheme's administrative costs. Consideration must be given to what uses this excess revenue could be put. The options fall into four categories.

7.1.1 Capital grants

The excess revenue could be used to provide grants to encourage firms to undertake investment and reduce their emissions. In the Netherlands, grants are available to meet the majority of the cost of treatment plants. France and Italy also have schemes to subsidise pollution reduction (see Appendix 2).

Such schemes should provide strong incentives for existing firms to cut discharges. However, they may have perverse effects on the incentives of new firms. For example, if a new firm is established it may adopt a lower cost, but a more polluting production technique, in anticipation of receiving a grant for a treatment plant.

The effectiveness of the grant system in France has been limited by the imposition of a revenue constraint on the river basin authority. In order for grants to achieve a significant improvement on water quality the total level of grants would probably need to be greater than the existing revenue constraint on the NRA. The effectiveness of such a scheme will depend upon the criterion used in the awarding of grants and the monitoring of firms actions.

7.1.2 Buying back of licences

The NRA has inherited a situation where in many areas licensed abstraction exceeds the optimal amount. Buying back these licences has proved difficult as licence holders place a high value on retaining the licensed capacity even where this exceeds their current abstraction. Excess revenue could provide additional funds to buy back existing abstraction licences. In principle discharge permits could be bought back in a similar fashion.

Both the buying back of consents and the awarding of capital grants could lead to public criticism that the "polluter pays" principle has been violated in that payments are being made to the "polluter". However from an economic perspective it can be demonstrated that an efficient solution can be reached either through charges on firms which lead to a target level of water quality, or by paying them to achieve the target quality level. There are however distributional effects in that a firm is clearly better off under the first scheme.

In the case of both buying back consents and capital grants the revenue has been raised from charges on abstractors and dischargers (though not necessarily those who receive the payments). The distributional effects are therefore less clear cut and such schemes may not be considered inequitable. However, such schemes may be susceptible to strategic behaviour on the part of firms.

7.1.3 Compensation payments

Excess revenue could be used to make compensation payments to parties who suffer economic loss as a result of abstractions or discharges. Compensation payments might conform to some notions of equity under the "polluter pays" principle. However, in economic terms compensation may not be the most efficient use of revenue.

Compensation payments may have a role in exceptional circumstances where water quality is seriously damaged by excessive discharges due to accident or negligence by dischargers. If firms face heavy fines for exceeding fixed discharge limits, it could be appropriate to pay some of these fines to injured parties.

7.1.4 Transfer to government as taxation revenue

The options for using excess revenues should be compared in terms of their effects on social welfare. This is likely to result in the decision that the revenues should be transferred to the Treasury for allocation to other purposes, such as education or social security. Such analysis is, of necessity, highly subjective, but would need to form the basis of an economic argument for the NRA retaining excess revenues rather than passing them to the Treasury.

The transfer of revenues to the Treasury would conform to traditional Government policy on social welfare grounds and also because the Treasury are reluctant to relinquish control over any aspect of public expenditure. However, protection of the environment is seen as having an increasing value, and ear-marked expenditure could be used to provide strong incentives to reduce pollution.

7.2 <u>Small scale users</u>

A particular issue which the NRA asked us to consider was the treatment of small dischargers or abstractors, for example septic tanks or domestic wells.

Arguments of economic efficiency and equity suggest that all dischargers or abstractors should pay for damage caused to others, no matter how small they may be. However, there are strong equity grounds for exempting small domestic abstractors and dischargers. It would seem unfair to set high charges for these agents as they have in general limited choice over the activity in question. In most cases they are not connected to the public water supply/sewerage system. The cost of connecting them to the system would in most cases be excessive.

Charging is unlikely to be able to generate significant incentives for householders to reduce discharges from septic tanks. In addition, since monitoring the actions of many small scale users is difficult, there may be a problem of charges encouraging the illicit disposal of waste.

The impact of each small user is generally small though it can be significant in localised areas or in instances where many such sources exist. There are likely to be significant administrative costs if charges are levied on small scale dischargers or abstractors and the enforcement of such charges could be difficult. In cost-benefit terms such charges are unlikely to be justifiable.

There are benefits from small abstractors and dischargers remaining registered. For instance the NRA will be able to locate near-by septic tanks in the case of a pollution incident being reported and to take account of existing small abstractors when considering new abstraction licence applications. Thus we recommend that small users remain on the abstraction and discharge registers and that the NRA considers charging an annual fee to cover the associated administration costs only. However we do not recommend that the incentive based charges scheme should cover such small users as it would be inappropriate given the limited scope for them to alter their behaviour.

One possible use of excess revenues would be to assist small users to reduce leaks from septic tanks, or to improve the quality of their abstraction. This would be a cheaper alternative than connection to the public supply system. If no charge is made for maintaining the register of such users then the administration costs could be covered by the revenue surplus from incentive charging schemes.

7.3 Application charges

The assessment of applications for discharge consents and abstractions licences is of key importance in determining how controlled waters are used. It is therefore essential that the NRA generates sufficient revenue to finance this activity. We recommend that the NRA retains an application charge for reasons of equity. The assessment of applications can be expensive and resource-intensive, particularly if detailed computer modelling is involved. It is therefore equitable to levy a charge that reflects the cost to the NRA of application assessment.

There is a possibility that levying an application charge may encourage would-be dischargers and abstractors to discharge or abstract illegally to avoid the application charge. This is most likely to occur if the application charge is high and the penalty for illegal abstractions and discharges is low. Thus the risk of this problem occurring can be minimised if the application charge is set at a reasonable level and there are severe penalties for illegal abstractions and discharges.

APPENDIX 1 - NRA'S NEW CHARGING SCHEMES

A1.1 Introduction

The NRA has recently introduced a charging scheme for discharges to controlled water and plans to introduce a new charging scheme for abstractions in early 1993. In this chapter we set out briefly the key features of these schemes, seek to understand the factors which underpin their selection, and assess the extent to which the schemes conform to the economic framework outlined in the paper.

A1.2 Charges for discharges

A new discharges charging scheme came into effect in July 1991. This scheme introduces a two element charging system:

- an application charge to recover the once-only costs associated with applications for new and revised consents;
- an annual charge for the recurrent costs of monitoring discharge consents and their impact on controlled waters.

The revenue raised by the charging system cannot exceed the level required to recover the NRA's administration costs. The NRA is prohibited by statute from levying charges in excess of these costs. The target for the first full year of operation 1992/93 is £41m with a target for the first nine-month period in 1991 of £25m.

The charging scheme is based on average costs throughout the NRA's ten regions. A proposal to adopt a charging system based on the actual costs imposed by each discharger, as is intended in Scotland, was rejected on the grounds that it would increase the overall costs and hence lead to higher levels of charges. It was decided that a national scheme would be more appropriate and would emphasise the national character of the NRA. However, this is likely to lead to regional surpluses and deficits. We understand that a decision as to how these regional imbalances are to be treated needs to be taken.

The application charge was introduced in October 1990 and set at £350 for a standard application and £50 for a reduced application charge where the amount to be discharged is small and the environmental impact is not significant. The application charge is a fixed amount and does not necessarily reflect the costs involved.

The annual charge calculation is a function of:

- Volume factor (Maximum daily volume of discharge under the consent);
- Content (What sort of pollutant it is);
- Receiving Waters (Coastal, Ground water etc);
- Financial factor (A unit charge to be set annually).

These variables are organised into bands, with each band assigned a weighting factor to reflect its relative contribution to NRA's monitoring and compliance costs. The number of chargeable units is determined by multiplying together the volume, content and receiving water factors. The unit charge, to be known as the financial factor, is to be set annually. The financial factor multiplied by the number of chargeable units determines the total annual charge.

The scheme is similar in structure to the combined quantity controls and charges described in Section 5.3. It differs significantly in its details in that the main purpose of the discharge charge is to recover the costs incurred by the NRA in administering the discharge consent system rather than to provide dischargers with an incentive to reduce their discharge load. Thus, the main control of water quality is via consent conditions. This reflects, at least partially, the fact that the level of charges is restricted by the legal requirement under the Water Act (1989) that the revenue raised by the NRA from discharge charges should not exceed the costs of administering the consent scheme. As a result the permissible level of charges is unlikely to provide firms with strong incentives to reduce their consent conditions.

A second major difference is that the discharge charge for a given discharger reflects the discharger's contribution to the NRA's costs of administering the consent scheme rather than its impact on water quality. This means that the charges actually provide dischargers with an incentive to voluntarily reduce their consents in order to reduce their contribution to the NRA's costs of administering the consent scheme rather than to reduce their impact on water quality. This approach is likely to provide dischargers with less effective incentives than the more direct one of charging in relation to the estimated impact of discharges on water quality.

A1.3 Charges for Abstractions

A new charging scheme for abstractions is to be brought into effect in early 1993. This scheme will replace the ten existing abstraction charging schemes that the NRA inherited. Below we briefly outline the nature of the existing abstraction charging schemes and their deficiencies before describing the key features of the proposed new NRA abstraction charging scheme.

Existing Schemes

The ten existing abstraction charging schemes inherited by the NRA display very significant variation. The schemes vary considerably in their complexity. For instance South West region employs only 5 charging bands whilst Severn Trent has as many as 108. There seems no obvious reason why such diversity should exist other than the fact that historically each scheme has developed separately. The report "Economics of Water Resource Management" (Report No. 0248), which we were asked to consider as part of this study, contains a detailed critique and appraisal of the existing schemes. The report's key findings are discussed here.

The factors which are used to determine charges vary across regions. They can be grouped under seven headings:

- source type;
- source quality;
- purpose/quality of return;
- quantity of return;
- location of return;
- season;
- number of charges.

No region includes all of these factors and some are considered by only one region. Within these headings the detail of the charging schemes varies greatly. Even the dates used for the winter/summer charging categories vary between regions. A prime aim of the new charging scheme for abstractions is to unify these disparate schemes into a single national scheme.

The report highlights a number of key weaknesses in the existing schemes. These include:

- the cost recovery nature of schemes means they fail to fully take into account resource and environmental costs;
- many schemes are extremely complex and not readily comprehensible to customers;
- many schemes fail to take account of the location of return flows and the seasonal variation in the value of returned water;

- under all schemes within each region the prices are uniform for a given set of factors. Spatial cost differences are not fully reflected;

- in some cases the role of incentive based charges is not fully appreciated even within the constraint of cost recovery with insufficient use of peak period charges.

New Scheme

The new abstraction charges scheme can only recover costs which are charged to the NRA's Water Resources Account. In addition to operating costs this includes a capital cost allowance based on an agreed rate of return on the NRA's water resource assets.

Within the cost recovery constraint the scheme is to be based on the impact of the abstraction on the water environment. A proposal that the scheme could reflect costs of the individual abstractors was dismissed as administratively cumbersome, and likely to increase the overall cost. Furthermore the water environment criterion was thought to be advantageous in that it fulfilled NRA's environmental responsibilities and would be fair and straightforward in application.

The main features of the proposed scheme are that the charge will be based on the following factors:

- Volume - the amount of water which is authorised to be abstracted each year;

- Period - the season of the year in which water is abstracted and the rate of abstraction used;

- Source - the nature of the source from which the water is abstracted;

- Point of return - the location of any return of water to a source.

An annual recurring charge will be based on the above variables, with weighting factors for Period, Source and Point of Return. As for discharges, the factors will be multiplied to give a combined weighting factor. The annual charge will then be calculated by multiplying the combined weighting factor, the volume of water authorised to be abstracted annually and the standard unit charge for the year. There is to be a national minimum charge for very small or low impact abstractions. The unit charge will be national and set annually in relation to the NRA's admissible costs which must be recovered.

The scheme is similar in structure to the combined quantity controls and charges described in Section 5.3. Control of the volume of abstractions is carried out through licence conditions, and the main purpose of the abstraction charge is to recover the costs charged to the Water Resources account.

This reflects the fact that the level of charges is restricted by the legal requirement under the Water Act (1989) that the revenue raised by the NRA from abstraction charges should not exceed the costs attributable to the Water Resources account. Even under this restriction, however, it may be possible to increase the abstraction charge to a level that provides abstractors with reasonably strong incentives by undertaking capital expenditure on water resource development.

The proposed system introduces national conformity and greatly simplifies the existing schemes. However the weakness highlighted in "Economics of Water Resource Management" that charges are uniform within each region is magnified with charges now uniform for given factors across the whole country. This fails to take account of the fact that water resources are essentially local. It may be preferable for spatial cost differences to be allowed for by the inclusion of the quality, rather than just the type, of receiving water as a factor.

APPENDIX 2 - INTERNATIONAL EXPERIENCE OF CONTROL SYSTEMS

A2.1 Introduction

In this chapter we review briefly the experience of selected countries in controlling discharges to and abstraction from water courses and identify the key features of their control systems. Particular attention is given to the extent to which reliance has been placed on the use of incentive based control systems and their effectiveness. We have restricted our survey to the following countries : France, Holland, Germany, Italy, and Scotland.

A2.2 Control of discharges

Below we summarise the key elements of the charging control mechanisms employed by the countries which we have surveyed.

A2.2.1 France

The French discharge charging system is intended to raise revenue for the River basin financial agencies. These agencies are responsible for two expenditure programmes: the pollution programme provides financial aid for treatment projects and the resource programme for raw water and quality projects.

The pollution charge applies to all agents who pollute either sea water or ground water. Household charges are fixed annually by municipalities. All other agents are charged a flat rate based on estimated consumption or are charged by measured amount. The level of charges is set nationally but varies between agencies as each agency is required to meet its breakeven revenue target.

Evaluation

The impact of pollution charges on levels of pollution is low due to the low levels of charges. There has been strong resistance to increases in charge levels and charges have actually fallen in real terms.

The agencies offer financial aid for anti-pollution measures and this has proved popular. However as self-financing bodies the agencies' only source of revenue is pollution charges. There is strong resistance to increases in such charges. Thus the self-financing nature of the agencies is the main weakness of the system.

The combination of economic incentives and direct regulation has had some impact on pollution, particularly organic pollution which has the lowest abatement costs. The system does not lead to a high degree of economic efficiency in terms of resource allocation but is administratively straightforward and compatible with the polluter pays principle.

A2.2.2 Germany

Germany is the only country which has an effluent charging system which is clearly incentive based. The system is supported by comprehensive direct legislation. The system is based on water quality goals with charges set for individual pollutants. Charges have increased significantly since its inception in 1981.

The distinctive element in the German charging system is the introduction of incentives by offering reduced charges according to the degree of compliance with the standards. If minimum emission standards are met a 50% discount is applied with further discounts for lower emissions.

Evaluation

Water quality has improved in Germany over the past decade but it is difficult to isolate the impact of incentive charges from the direct regulation. The incentive impact is likely to be low as the charges are far too low to cover all the costs of damage. Average treatment costs are four times average pollution charge levels.

However several large companies have reduced emissions to below the minimum level, and one-third of municipalities state that the charge was the main reason for intensifying water treatment. Estimates suggest the economic efficiency of the policy is reasonable with an incentive to adopt more efficient solutions. There is some evidence that the policy has helped to promote the rapid improvement in pollution abatement technology.

The charges are in accordance with the "polluter pays" principle. The administrative efficiency of the system is low with half of all revenues spent on administration. The incentive effect is reduced by the low level of charges.

A2.2.3 Holland

The Dutch employ a mixed effluent/user charge system linked closely with direct regulations. There are two distinct systems in Holland :

- discharges into State waters (including Water Boards) are subject to charges from the State Water Authority which uses the revenue to subsidise water treatment;

- all other discharges are subject to charges from the Water Boards. These Boards operate on a revenue neutral basis and so charge levels vary by region.

Charge levels are considerably higher than elsewhere in Europe and have increased over time.

Evaluation

The charging system has had a major impact on pollution levels in certain industries such as chemicals, beverages and tobacco. Studies suggest that the charging system had a greater effect than direct regulation or negotiations between firms and monitoring authority.

The system is viewed as moderately efficient in economic terms and administratively very efficient as only a small percentage of revenue is taken up by management costs. The charging system performs moderately well when judged against the "polluter pays" principle. This could probably only be improved by the introduction of more complex schemes with a consequent lack of clarity.

Difficulties have been encountered in tracing diffuse sources of pollution. Extension of the system to organic micropollutants will increase technical and monitoring problems.

A2.2.4 Italy

The Italian system of effluent charges is in some respects similar to the German with incentive charges linked to direct controls. There are two charges; a user charge to finance the sewer system and water treatment and an effluent charge intended to encourage polluters to meet the pollution limits "as soon as possible". The purpose of the first charge is revenue raising, the purpose of the second is incentive based.

Charges are based on the volume of wastewater, the water quality, treatment plant characteristics, average treatment costs, and a reduction factor. The reduction factor represents the incentive factor. Those firms who do not meet provisional pollution limits face charges up to nine times higher than those who do comply. The factor increases over time to encourage speedy compliance.

Evaluation

It is difficult to evaluate the policy on the basis of available evidence. The charge is in reality a non-compliance charge. It is intended that the charge will be abolished once full compliance with water pollution law at definite pollution limits is achieved. The charge does not follow the polluter pays principle closely as there is only a weak link to actual water quality through broad charging bands. The charge is based on estimated quantities as monitoring is infrequent.

A2.2.5 Scotland

The Scottish River Purification Boards' Association (SRPBA) has issued a proposed charging scheme for discharges to water courses. The scheme is similar in many respects to that proposed by the NRA and informal discussions have been held between the two bodies. The Scottish proposal aims to charge dischargers for the work necessary to maintain proper environmental control over their discharges. Each River Purification Board aims to introduce its own scheme based on common guidelines by April 1992. The main objectives of the proposed scheme are:

- to discourage pollution by making dischargers aware of the costs involved;
- to allocate charges in proportion to the workload imposed by dischargers;
- to enable the Board to recover costs arising from specific discharges by direct charges and only recover costs associated with general duties from taxation (through the community charge).

The SRPBA scheme like that of the NRA has two aspects; a charge for processing consent applications, and an recurrent charge to cover the costs of monitoring the consents and general environmental monitoring in relation to the consents.

- the proposed application fee is the same as that under the NRA scheme; £350 standard and £50 reduced;
- the annual charge is set to recover monitoring costs. It is intended to recover the same costs as the NRA scheme but takes a different approach to the setting of individual charges.

The annual charge will be directly related to the appropriate monitoring costs and comprises three elements:

The standard attendance charge

This charge covers the average cost of inspection, collection and transportation of samples

The compliance monitoring charge

This charge covers the actual cost of analysing samples and reporting results. The charge is to be based on the type of analysis and frequency of sampling as specified in the authorities annual plan (to be reviewed annually). The charge is determined by the analytical unit cost multiplied by analytical units for each monitored substance. This differs from the NRA scheme where the content weighting factor is determined by the highest band into which any monitored substance falls.

The environmental monitoring charge

This charge would cover the costs to the authority of monitoring the effects of the discharge on the quality of receiving waters and their animal and plant life.

In addition to the above there is a separate Enforcement Sampling Charge which covers the cost of additional sampling taken during periods when effluent discharges are outside of the consent period. This charge will be a higher rate to cover the more complex nature of enforcement sampling.

Comparison with the NRA scheme

The main difference between the Scottish proposal and the NRA scheme is that the annual charge under the Scottish scheme relates to a pre-determined sampling/monitoring programme set for each consent and calculated to recover the total costs incurred under each separate function. By contrast the NRA scheme has only one annual charge for each discharge which is set to recover the total costs incurred. The charge for each consent is set by applying the appropriate weighting factors to the bands in which the volume, content, and receiving water of the consent apply. The weighting factors are determined by applying the NRA's general monitoring policy to the costs of the separate NRA monitoring functions. The NRA scheme does not include provision for additional charges for enforcement sampling.

The matching of income with costs over separate heads in the Scottish heads might suggest greater accuracy. However this accuracy may be spurious due to the inevitably subjective nature of cost apportionment between heads.

The revenue matching nature of the Scottish scheme has the drawback that changes in the monitoring scheme may be necessary, as procedures are standardised, without changes in charges. In addition monitoring schemes may change during the course of the year for which charges have been set.

The NRA rejected similar proposals to the Scottish scheme on the grounds that the additional analysis of charges and expenses which would be required would inevitably increase costs and these costs would have to recovered through the charging scheme. The SPBRA has decided that this was offset by the ability of the scheme to charge as closely as possible the costs incurred for individual discharges. The Scottish scheme attempts to achieve greater accuracy by basing charges on actual monitoring costs per discharge although the benefit of this approach is reduced to the extent that the cost allocation is itself somewhat arbitrary. The Scottish scheme allows for each River Purification Board to be self financing as each sets its own individual charging scheme.

A2.3 Abstraction charges

There is much less published information on the use of abstraction charges in Europe than is the case for charges for discharges. We were only able to locate information on two of the countries considered.

A2.3.1 France

The River Basin Financial Agencies levy abstraction charges for both surface and groundwater. There are several cost bands with relative scarcity determining the level of charge. Groundwater attracts a higher abstraction charge. Charges do not vary with the quality of water.

A2.3.2 Holland

Licences are required for any abstraction. Charges are based on cost recovery with surface abstraction being more expensive than groundwater abstraction.

Firms abstracting for industrial use require a licence and pay a volume charge which is set at nominal levels. Charges for industrial abstraction of groundwater are based on total pollution load rather than additional pollution. Water used for cooling purposes is charged on the basis of water not returned. In some regions charges are progressive to dissuade large abstractors. In other areas charges are flat rate or regressive.

APPENDIX 3 - EMPIRICAL STUDIES ON MARKET-BASED INSTRUMENTS

A3.1 Marketable permits on the Fox River

The main empirical evidence on marketable permits for water pollution control comes from a scheme established in the early 1980s on the Fox River in Wisconsin. The Fox River is heavily industrialised and at this time there were ten paper and pulp mills and four sewage works located along a 22 mile stretch of the river. In summer months discharges from these industrial sources led to violations in the dissolved oxygen quality standard, even though all the firms met the relevant emissions regulations.

In 1981 the Wisconsin Department of Natural Resources set up a system of ambient permits with the aim of reducing the cost of meeting the dissolved oxygen standard. Simulation studies indicated the cost of meeting the standard could be reduced by about $7m per annum if permits were used instead of uniform emission standards. Unfortunately, very few permit trades have occurred, and the cost savings which have been realised are minimal. As a result the permit scheme is widely regarded as a failure. A number of reasons have been suggested for this, including:

- the permit market is thin due to the small number of firms involved;

- firms may regard permit ownership primarily as a means of obtaining advantage over their rivals rather than as a means of reducing their own abatement costs;

- permit trades are subject to several restrictions which effectively reduce the number of potential trades. For example, firms must justify their "need" for permits;

- the marketable permit system forms a relatively small part of a regulatory structure in which the main emphasis is placed on treatment standards and operational rules.

A3.2 The Tees Study

In 1974 the DoE commissioned a study of the relevance of charges as a control device for improving the water quality of the Tees Estuary. The Tees Estuary at that time was heavily polluted with industrial effluent and raw sewage and was considered to be incapable of supporting fish life.

Using information obtained from the main polluters and from a previous study carried out by ICI, a computer optimisation model was developed to calculate a least cost investment programme for the whole estuary of attaining certain quality levels by specific target dates.

Another computer model was also developed to calculate a unit charge for each pollutant at 0.3 mile intervals along the river with the objective of inducing the minimisation of the dischargers' production costs.

The study concluded that an investment of between £12m and £20m (1976 prices) would be required to improve the water quality, depending on the specific target and implied that dischargers would pay annual total charges of between £12m and £16m. Some of the main conclusions were:

- **Sensitivity of the least-cost solution to quality standards** - For example, increasing the requirement for DO from 5ppm to 6ppm required a substantial cost increase.

- **Economies of Scale** - The large economies of scale involved in sewage treatment meant that a charging scheme applied alike to industrial dischargers and STW operators, would not necessarily achieve the least cost solution.

- **Variation of charges** - Large variations in unit charges (up to 2 orders of magnitude) for each pollutant along the estuary were required in order to achieve the least-cost abatement programme.

- **Sensitivity of the cost-abatement programme to unit charges** - The study found that the choice of charge was crucial if the investment programme for certain water quality standards was to be achieved at least cost.

- **Limited Information Policies** - The study examined the impact of both charging and regulatory policies in the absence of full information about the dischargers' abatement options. It concluded that adopting a unit charge approach resulted in abatement programmes costing between 30% and 110% more than the least cost programme. Similarly, a uniform percentage reduction (regulatory) policy resulted in cost excesses of between 30 and 70%.

APPENDIX 4 - MATHEMATICAL APPENDIX

The Model

Suppose that there are n firms, labelled 1, 2, ..., n. Some of these firms are abstractors and some dischargers. Suppose that there are m-1 different pollutants which may be discharged. The use which the i^{th} firm makes of water resources may be represented by a vector

$$x_i = (x_{i1}, x_{i2}, \ldots, x_{i\,m-1}, x_{im})$$

where $x_{i1}, x_{i2}, \ldots, x_{i\,m-1}, x_{im}$ are the quantities of the various pollutants discharged and x_{im} is the quantity of water abstracted.

We consider k different water quality measures. We wish these measures to attain certain water quality standards. The water quality measures would typically relate to many different pollutants and be measured at many different locations in the water resource. Each water quality measure is a function of the discharges and abstractions of each firm. In particular, we suppose that there is a 'pollution model', which is a set of functions:

$$Q_j (x_1, x_2, \ldots, x_n) \text{ for } j=1, \ldots, k,$$

relating the j^{th} water quality measure to the actions of firms. Let s_j denote the water quality standard which the j^{th} water quality measure must meet. This pollution model assumes that water quality depends only on contemporaneous discharges and abstractions, and so ignores dynamic effects. We make the technical assumption that the Q_j functions are quasi-convex*. This assumption has an intuitive interpretation as requiring that spreading a given quantity of abstractions or discharges across all firms should have less effect on water quality than concentrating discharges or abstractions in the hands of a few firms.

The abatement cost of a firm is a function of its abstractions and discharges of various pollutants. Denote the abatement cost of the i^{th} firm by $c_i(x_i)$. It is assumed that these cost functions are differentiable and concave. These assumptions rule out non-convexities in the abatement technology. If non-convexities are present, the abatement cost functions need not be differentiable (or even continuous).

* This means that $\{(x_1, x_2, \ldots, x_n) \text{ s.t. } Q_j (x_1, x_2, \ldots, x_n) \geq y\}$ is a convex set for all y.

In order to minimise total abatement costs, we must solve the optimisation problem:

$$(1) \qquad \text{minimise} \sum_{i=1}^{n} c_i(x_i) \text{ subject to}$$

$$Q_1(x_1, x_2, \ldots, x_n) \geq s_1$$

$$Q_2(x_1, x_2, \ldots, x_n) \geq s_2$$

$$\vdots$$

$$Q_k(x_1, x_2, \ldots, x_n) \geq s_k$$

This problem can be easily solved by introducing a Lagrange multiplier for each constraint. Let λ_j be the Lagrange multiplier associated with the jth water quality constraint. The first order conditions are then:

$$(2) \qquad \frac{\partial c_i}{\partial x_{ip}}(x_i) + \sum_{j=1}^{k} \lambda_j \frac{\partial Q_j}{\partial x_{ip}}(x_1, \ldots, x_n) = 0$$

These first order conditions can be interpreted in the following way. λ_j is the shadow price of the jth water quality measure. $\frac{\partial c_i}{\partial x_{ip}}$ is the marginal cost to the ith firm of abating the p^{th} pollutant (where p=m is interpreted as an abstraction). $\frac{\partial Q_j}{\partial x_{ip}}$ is the marginal effect of the i^{th} firm's discharge of the p^{th} pollutant on the j^{th} water quality measure.

The values of the λ's are determined by the Kuhn-Tucker conditions:

$$(3) \qquad \begin{array}{l} \lambda_j = 0 \text{ and } Q_j(x_1, \ldots, x_n) > s_j \\ \text{or} \\ \lambda_j > 0 \text{ and } Q_j(x_1, \ldots, x_n) = s_j \end{array}$$

These conditions require that either a particular water quality constraint binds and the corresponding λ is strictly positive, or else that the water quality constraint is slack and the corresponding λ is zero. Those water quality constraints which bind can be regarded as pollution 'hot spots'; these water quality measures have a positive shadow price, reflecting their scarcity value.

The cost minimising discharge plan can be found by solving the system of simultaneous equations defined by equations 2 and 3 for the variables x_{ip} and λ_j. Let $\tilde{x}_{ip}$ and $\tilde{\lambda}_j$ denote the solution to these equations, which is the cost minimising solution.

Implementing the Cost Minimising Scheme through Charges

What charges should be set to force firms to adopt the abatement cost minimising discharges $\tilde{x}_{ip}$? The answer to this is to charge each firm a volumetric charge for discharge of each pollutant type which is related to its marginal impact on water quality at the cost minimising discharge level. The total discharge bill is

$$\sum_{p=1}^{m} x_{ip} v_{ip}$$

where v_{ip} is per unit charge set for the i^{th} polluter to discharge the p^{th} pollutant (or abstract if p=m) and equal to

$$v_{ip} = \sum_{j=1}^{k} \tilde{\lambda}_j \frac{\partial Q_j}{\partial x_{ip}} (\tilde{\mathbf{x}}_1, \tilde{\mathbf{x}}_2, \ldots, \tilde{\mathbf{x}}_n)$$

Firms will individually try to minimise the sum of their abatement costs and pollution charges. Thus the i^{th} firm minimises

$$c_i (\mathbf{x}_i) + \sum_{p=1}^{m} x_{ip} v_{ip}$$

by choosing its discharge levels. In particular the first order condition for choosing the discharge level x_{ip} is

$$\frac{\partial c_i}{\partial x_{ip}} (\mathbf{x}_i) + v_{ip} = 0$$

or

$$\frac{\partial c_i}{\partial x_{ip}} (\mathbf{x}_i) + \sum_{j=1}^{k} \tilde{\lambda}_j \frac{\partial Q_j}{\partial x_{ip}} (\tilde{\mathbf{x}}_1, \tilde{\mathbf{x}}_2, \ldots, \tilde{\mathbf{x}}_n) = 0$$

Clearly firms will choose discharges equal to cost minimising ones $\tilde{x}_{ip}$ under this charging scheme.

Implementing charges without knowing abatement costs

The main problem with the charging scheme laid out above is that a large amount of information is required by the regulatory body. In particular the regulator needs to know the pollution model (ie the Q_j functions) and the abatement costs (ie the c_i functions). One way round this problem is to use a pollution model to determine the structure of charges (ie how relative charges should be set for different firms) and then to experiment with the level of charges until the desired water quality targets are met. In terms of the framework above, this means experimenting with different values of the λ's in order to implement the water quality targets.

One possible scheme would be to levy charges of the form:

$$\sum_{j=1}^{k} \hat{\lambda}_j Q_j (x_1, x_2, \ldots, x_n)$$

where $\hat{\lambda}_j$ is a guess at the shadow price of the j^{th} water quality measure. This scheme has a simple interpretation. Each water quality measurement is given a notional price ($\hat{\lambda}_j$) and firms charged according to the reductions is water quality which they cause, valued to these prices. The $\hat{\lambda}$'s determine the *level* of charges for each particular pollutant, whereas the impact of individual firms on water quality determine the *structure* of charges.

One problem with the charging scheme above is that the bill paid by one polluter depends on the actions of others. One way around this is to set a volumetric charge for the i^{th} firm and p^{th} pollutant with price equal to

$$\sum_{j=1}^{k} \hat{\lambda}_j \frac{\partial Q_j}{\partial x_{ip}} (\bar{x}_1, \bar{x}_2, \ldots, \bar{x}_n)$$

where $\bar{x}_{ip}$ is a guess at the cost minimising discharges. This guess could simply be the current discharge levels of firms.

Given a particular set of notional water quality prices ($\hat{\lambda}$'s) the charges proposed above will result in particular water quality levels. The water quality levels attained will be functions of the charge levels. This can be represented by expressing the j^{th} water quality level as a function of the water quality prices:

$$f_j(\hat{\lambda}_1, \hat{\lambda}_2, \ldots, \hat{\lambda}_k)$$

It is important to note that the j^{th} water quality measure may depend on the notional price of all water quality measures, not just the price of the j^{th} water quality measure. This is represented by f_j being a functions of all the $\hat{\lambda}$'s, not just $\hat{\lambda}_j$. The reason for this is that there may be interrelationships between the different pollutants in the abatement costs of polluters. For example, two different pollutants may be produced in constant proportion to the output of a firm; charging for the discharge of one of these pollutants will cause a contraction in the output of the firm and so a reduction in the output of *both* pollutants.

Under this charging scheme the regulator will seek to adjust the water quality prices ($\hat{\lambda}$'s) until the target water quality levels are achieved. Formally, this means choosing the $\hat{\lambda}$'s such that

$$f_j(\hat{\lambda}_1, \hat{\lambda}_2, \ldots, \hat{\lambda}_k) = s_j \text{ for } j=1, \ldots, k$$

The regulatory can seek to achieve these water quality targets by experimenting with the water quality prices until the target levels are met. Providing that the j^{th} water quality is an increasing function of the j^{th} water quality price this is easy to achieve. Those pollutants for which water quality is below its target level should have their prices (ie the appropriate $\hat{\lambda}$) increased; those pollutants for which water quality is above its target level should have their prices decreased. Under this procedure water quality will converge to its target levels. It is important to note that this adjustment procedure requires that the j^{th} water quality is increasing in the j^{th} water quality price (ie f_j is an increasing function of λ_j). This situation is often referred to as 'gross complementarity'.

APPENDIX 5 - TERMS OF REFERENCE

TITLE:

New style charging schemes for discharges and abstractions

OBJECTIVES - overall

To set out the issues to be considered and the action to be taken by the NRA in developing the use of economic instruments for environmental regulation and protection.

Specific Objectives:

1. To assist the NRA to contribute effectively in respect of its water regulatory function.

2. To identify the needs for data-collection and other internal actions the NRA should undertake.

3. To identify the principles and factors deciding or influencing the levels of charges and the total level of income to be collected once this exceeds "cost recovery" in one or another definition.

4. To identify in principle, the scope for exempting from charges at a more-than-cost recovery level small abstractions and discharges (such as household wells and septic tanks) still required to be covered by permits recorded in public registers: the avoidance of undue discrimination and sustaining equity in public perceptions of the charges is a significant consideration here.

Other points that should be discussed include:

5. (i) The broad forms of graduation of charges between permit-holders to be considered for adoption.

   (ii) The relationships and similarities/differences between possible capacity charges for abstractions and for discharges.

   (iii) The considerations in favour or against charges to be set in regional or sub-regional areas, or on a uniform national tariff. Graduations between e.g. upstream, estuary, coastal locations should be discussed as well as differentials between catchments/regions. Questions of the accounting format in relation to e.g. cross-regional transfers of income should be addressed here.

(iv) The effective use of income beyond the expenditure in administering/enforcing the regulatory systems, including among the options: capital grants to point dischargers ready to reduce their claims on the environment; expenditures (direct or indirect by others) on the reduction of diffuse sources of pollution, including the training of relevant personnel in industry and agriculture. Hazards and objections to these and other options should be identified as well as benefits.

(v) Whether charges for consent applications should be a permanent feature of the charging system.

(vi) Any other aspects of principle, such as whether income should be applied to other broader purposes, such as fisheries work or the restoration of amenity in urban areas subject still to gross river pollution.

BACKGROUND:

In developing its role as an effective environmental regulator, the NRA needs to investigate and develop charging policy methodologies. This consultancy will enable the NRA to discuss charging policy and its implications inside and outside the organisation.

At the first stage, including specific numbers or levels of charge may form only a small part of the study, and to that extent, discussions of the economic impact of the charges on current abstractors/dischargers cannot be firm or precise. However, indications of European experience in this aspect could be relevant and helpful, and the consultant should take explicit account of this general aspect at all points in the report (including the passages on graduation and differentials) where it is practical and realistic to do so.

This study is related to NRA permit systems only. The consultant need not relate to controls or charges that HMIP may be developing.

CONTEXT:

1. The consultant will develop the study from:

   (i) Annex A to the Government's Environment White Paper.

   (ii) The charging schemes for discharge consents and abstraction licenses currently in operation, having regard to the history of abstraction licence charging as generally acceptable in its format over 20+ years.

   (iii) Such experience of charging schemes for environmental capacity in Europe as appears comparable and relevant to England and Wales.

2. The consultant will consider other projects and reports submitted to the NRA, in particular;

   - WRc report on Comparison of charging practices for effluents in three EC member states - April 1990;
   - Project 248 - Economics of water resources management;
   - Project 253 - Economic value of changes to the water environment.

3. The consultant will take reference of work currently being undertaken by the DOE Environmental Protection Economics Division.