ECONOMIC INCENTIVES IN CONTROLLING POLLUTION IN THE SOUTH AFRICAN LEATHER INDUSTRY

THESIS

SUBMITTED TO RHODES UNIVERSITY IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SOCIAL SCIENCE

by

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ABSTRACT

The objective of the research was to ascertain whether, when compared to a system of standards, the theoretical promise that economic incentives offered as a low cost solution to the abatement problem, would hold in practice. This was done by applying environmental economic theory to the practical problem of controlling the effluent generated by firms in the South African leather industry. It was found that in this instance the theory did indeed hold in practice. Furthermore, it was found that of the incentives discussed by the theory, marketable permits were the most economically efficient. It was however shown that a charge - not discussed in the theory - based on a central treatment agency's (CTA) cost of treatment offered the least cost solution to the abatement problem when the CTA could do at least some of the effluent treatment at a lower cost than the firms. In addition a formula was developed to show the net benefits accruing to an individual firm if it undertook to treat its effluent. It was shown that in order to maximise the total benefits of treatment, a firm should treat until its net benefits of treatment were zero.

A number of problem however were found to exist when the theory was applied to a practical situation. The most important was the "stepped" nature of the firms marginal abatement cost curves which meant that the setting of a charge based on a trial and error method would prove to

be more difficult than the theory envisaged. Furthermore, it meant that no matter what method of pollution control was used, it would prove impossible to reduce effluent to an optimal level.

It was recommended that greater use be made of economic incentives to control all industrial effluent. It would nonetheless be necessary to do more research in this field as the theory was not tailor made for all practical situations. Further evidence of the viability of economic incentives could however encourage wider use by policy makers.

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CHAPTER 1 HISTORICAL BACKGROUND AND CURRENT STATUS OF THE SOUTH AFRICAN LEATHER INDUSTRY

Pollution of the environment is becoming an increasingly serious problem. A large contributor to this is industry, which generates effluent as a by-product of its production process. The two main methods of controlling the pollution generated by industry are so called "command and control" techniques and economic incentives. In theory economic incentives promise a more economically efficient and equitable means of pollution control. This study sets out to ascertain whether this would hold in practice by applying environmental economic theory to the practical problem of controlling the effluent generated by one particular industry, namely the South African leather industry.

The first chapter serves to set out the context of the leather industry in South Africa by offering a brief history of the industry and a broad outline of its contribution and importance to the South African economy.

The origins of the leather industry in South Africa can be traced back to the days of the early Dutch settlement at the Cape when it was "natural for the hides and skins of slaughtered animals to be converted into articles of use by the primitive methods available" [Shuttleworth, 1983:12]. In its early years the leather industry was very closely linked to the footwear industry as this was the destination for most of its produce.

In 1904 the leather industry faced something of a crisis. At the end of the Boer war local manufacturers had to contend with a shortage of hides due to the war and the rinderpest. While by 1904 sufficient hides were available, imported leather, mainly from Argentina, had obtained a "grip on the market" and was selling at so called "dumped prices", bringing the local leather industry to a virtual standstill (Schauder,1935:516).

By 1910 the leather industry was still finding difficulty with imports while the footwear industry was relatively prosperous. This led to conflict in so much as the leather industry strenuously sought to secure "increased protection for their product." This was "strongly opposed" by footwear manufacturers, who sought to purchase their raw materials at the lowest possible price (Schauder,1935:521). This did not however deter footwear manufacturers from applying for greater protection in the 1920's.

It is interesting to note Schauder's (1935:537) view that "the first condition for the welfare of the South African tanning industry is a flourishing boot industry and the latter's needs therefore must be given precedence when the interests of tanner on the one hand and shoe manufacture on the other, appear to clash." The close link between the two industries is further illustrated by the fact that by 1922, 80% of the total output of the tanneries was taken up by the footwear industry.

Both the leather and footwear industries continued to develop to the extent that the "existence of a well equipped tanning and footwear industry during world war 2 resulted not only in the ability of local manufactures to supply the footwear needs of the country, but also in the production of millions of pairs of army boots for the Allied forces" [Shuttleworth,1983:15].

"In the post war period a major threat to leather was the development of numerous synthetic substitutes. The fact that the available skins and hides of the world were totally used and fetched reasonable prices, indicated that on balance leather held its own" [Shuttleworth,1983:16].

The growth of the leather industry is generally ascertained from the "quantities of hides and skins soaked." Using this criterion, the tanning industry grew "much more slowly than the footwear industry during the period 1956-1965 and then almost twice as fast in the subsequent 15 years." According to Shuttleworth [1983: 16] this can be attributed to the "encouragement given through customs tariffs as well as hide utilisation incentives. These factors enabled the industry to replace some of the higher grades of leather which had previously been imported and to export partially and fully processed leather."

The heavy reliance of the leather industry on the footwear industry continued until the early to mid 80's. The footwear industry had increased production to meet the "demands of population growth and rising living standards. Tanneries increased their capacity in concert to a level where they utilised nearly all hides of reasonable quality and leather production rose with most of it destined for domestic shoe production" (O'Shaughnessy,1994:19).

"From the mid 1980's on, calls for upholstery and automotive leathers climbed." This trend has continued and resulted in tanneries expanding further. "The production of automotive leathers in South African has made fantastic strides over the last three years." The origins of this, according to O'Shaughnessy (1994:20) lie in the "global nature of the car industry, with components, including leather upholstery and trims, being traded and exchanged by companies in their plants the world over".

A second cause is specific to the South African motor industry and is rooted in the local content programme.

The South African government has long encouraged industry to maximise local content in all spheres, irrespective of whether products are for domestic use or exports. The most recent phase of the programme put the stress on the "local content measured by value, rather than on weight, the more easily attainable formula used previously" (World Leather,1992:30).

This has proved an inducement to motor plants to export "relatively low tech, but high valued, car parts to their parent companies in Europe and thereby gain excise and custom duty rebates." Leather seats and trims, especially in the luxury car ranges, fit this requirement perfectly (World Leather,1992:30).

Production of upholstery leathers increased demand for quality feedlot hides. However, only about "50% of South African hides are suitable for processing to auto leather because of the stringency of motor trade specifications. This has lead to South African tanners developing ties with European based tanneries and importing selected wet-blue hides to sweeten their mix. European tanneries in turn are following the market to this country and investing in leather production facilities" (O'Shaughnessy,1994:20).

"Rising demand for automotive leather has resulted in footwear manufacturers facing a distinct shortage of raw materials", particularly so because, as mentioned earlier, "the prices that they offer do not compare with those of even the cheaper grade upholstery line." Therefore nearly "50% of South African leather production is now tied to upholstery" (O'Shaughnessy,1994:22).

Other trends, not specific to South Africa, in the leather industry, include the development of the Tritan system and the Permair foil. The former upgrades splits (low quality leather) by laminating a polyurethane cover onto the split. The resultant product can then be moulded into any shape and has an appearance and texture not unlike high quality finished leather. The major disadvantage of this system is that, unlike leather, it cannot "breathe". The Permair foil is basically the same with the important distinction that it cannot be moulded into any shape and, as the name would suggest, it is able to breathe. Both therefore essentially upgrade existing leather by adding more value to the existing raw material (Jackson-Moss, 1995).

At present the South African leather industry comprises 21 tanneries and 2 fellmongers. Their geographical distribution is illustrated in figure 1.1.

In world terms, with the exception of the automotive upholstery production discussed earlier, the South African leather industry is relatively insignificant. For

Figure 1.1: Geographical distribution of South African tanneries and fellmongers

Source: Jackson-Moss, 1995

KEY

1. Alpha Leathers
   New Germany
2. Edendale Tannery
   Edendale
3. Gringo Leathers
   Uvongo
4. Ladysmith Lingens Leathers
   Ladysmith
5. Aquaterra
   Sun City
6. Kwiktan
   West Krugersdorp
7. Oryx Tanning
   West Krugersdorp
8. Oscroc
   Florida
9. Rodeo Tannery
   Theresa Park
10. Hanni Leathers
    Nigel
11. Hidskin Processors
    Johannesburg
12. Bader Bob Tannery
    Rosslyn
13. Velskin Products
    Hammanskraal
14. East Cape Tanning
    Uitenhage
15. Exotan
    Port Elizabeth
16. G.H. Hackman,
    Port Elizabeth
17. Pelts Products,
    Port Elizabeth
18. King Tanning Company
    King williams Town
19. Klein Karoo Landbou Ko-op
    Oudsthoorn
20. Corium (Pty) Ltd
    Wellington
21. Western Tanning Company
    Wellington
22. Richard Kane Fur Skins
    Cape Town
23. Mossop Leathers
    Parow

Notes: 1. Fellmongers

example, the United States produces more leather in 3 weeks than the South African industry produces in a year. This can be further illustrated by figure 1.2 which shows the world output of leather in 1988, by region.

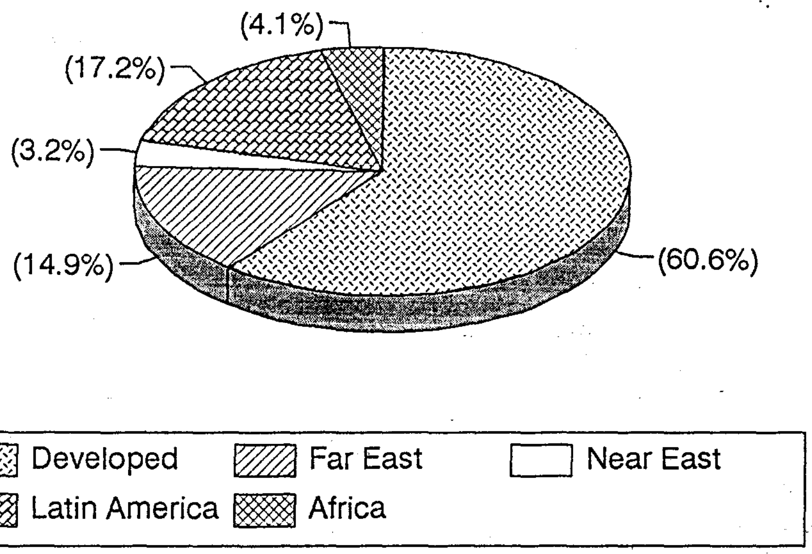

Figure 1.2: World leather production by region

Source: Felsner, 1995

As can be seen from figure 1.2, Africa as a whole accounted for only 4.1% of the world's output. In an African context however, South Africa is, in the words of Sweetnam (1995) a "major player". In terms of size it ranks as one of the biggest in Africa and is by far the most sophisticated on the continent (Sweetnam, 1995). This can be illustrated by comparing the size of the livestock populations, the recovery rate of hides and skins and the number of tanneries and fellmongers for South Africa and other African countries.

Table 1.1: Cattle populations and recovery rates: South Africa and selected African countries

Country	Cattle population	Recovery rates (%)
Zimbabwe	2 000 000	15-20
Ethiopia	30 000 000	7
Malawi	837 000	8-12
Sudan	22 200 000	8
Tanzania	12 776 000	8
Uganda	4 729 000	13
Zambia	500 000	15-17
South Africa	8 200 000	100$_1$

Source: Felsner, 1995

Table 1.2: Sheep populations, recovery rates and number of tanneries: South Africa and selected African Countries.

Country	Sheep population	Recovery rates (%)	No. of tanneries
Zimbabwe	3 900 000	1-3	5
Ethiopia	24 000 000	33	8
Malawi	101 000	5-10	1
Sudan	22 000 000	24.9	8
Tanzania	3 556 000	25	5
Uganda	1 066 000	13	3
Zambia	2 700 000	12	4
South Africa	25 071 000	100[1]	23

Source: Felsner, 1995

Notes: 1. Recovery rates from the formal sector (i.e controlled abattoirs) is 100%. There are no figures available for the informal sector although hides and skins are procured from these sources.

In terms of the South African economy, the leather industry employs approximately 10 000 people directly with a further 22 000 employed in associated industries such as the footwear industry (Sweetnam, 1995). In 1994 the industry's contribution to the manufacturing sector was 0.5% of Gross Domestic Product (S.A. statistics, 1994: 6.10).

The value of the sale of leather products was, in 1994, just over R1.2 billion (S.A. statistics, 1994). The trend for the 5 years before that is illustrated in figure 1.3. Taking into account inflation over the period would in fact constitute a decline in real terms.

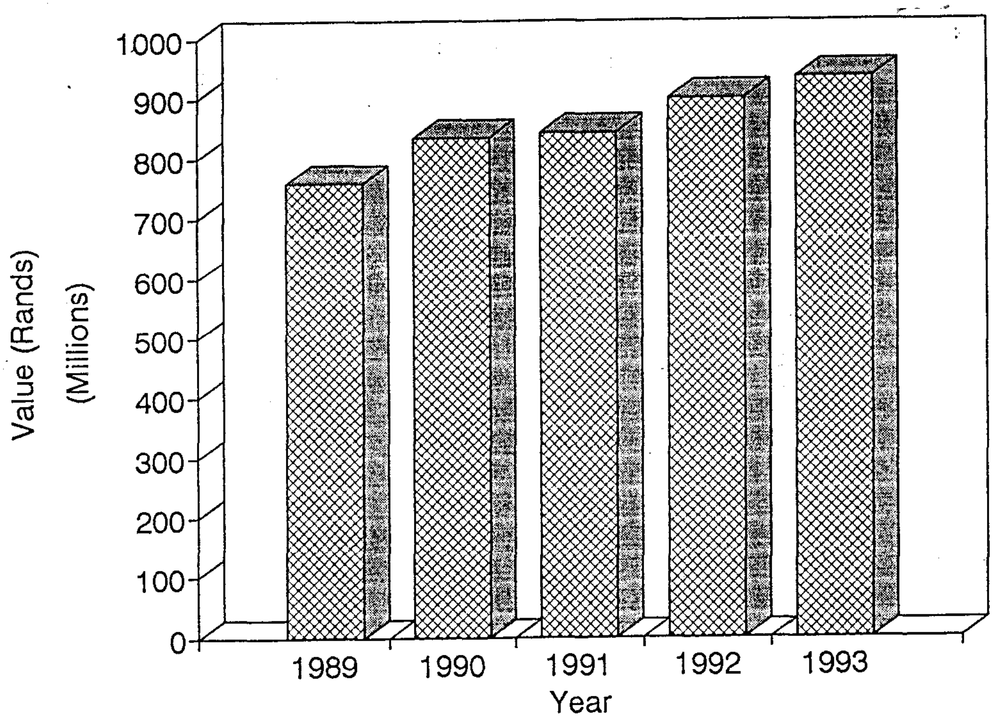

Figure 1.3: Value of sales: South African leather products: 1989-1993

Source: S.A. statistics, 1994, 12.63

In terms of imports and exports South African tanneries and fellmongers are net exporters of processed leather. By processed it is meant that the hides have been taken to at least the wet-blue stage and the skins to the so called pickled pelt stage. This is illustrated below in figure 1.4.

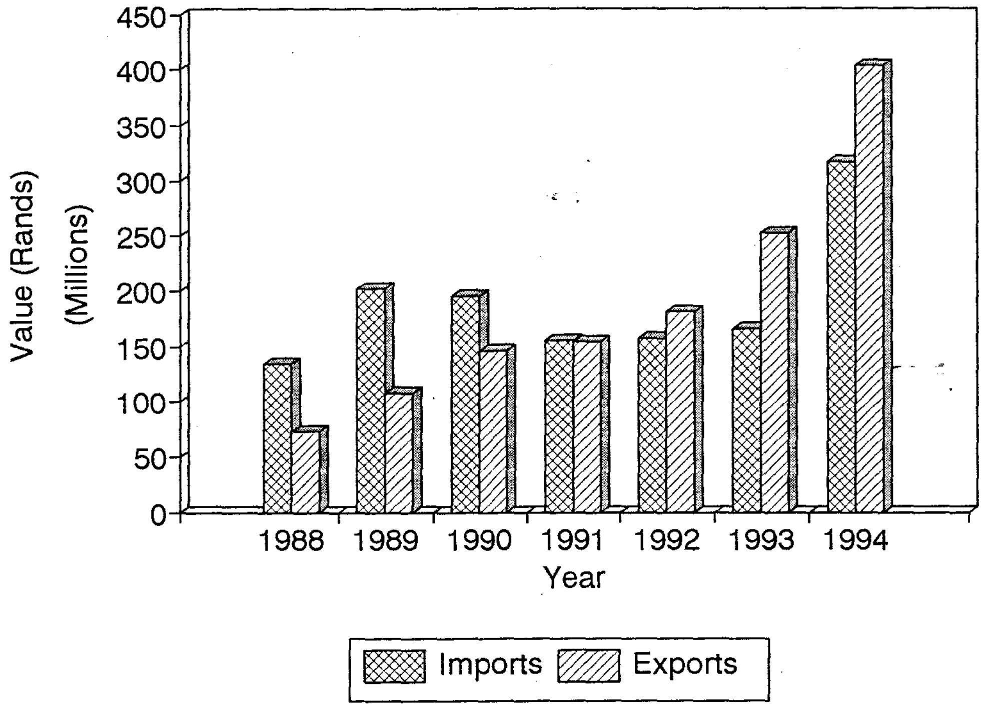

Figure 1.4: Exports and imports of leather by South African tanneries and fellmongers

Source: Swanepoel, 1995

The amount of hides and skins processed locally as well as the number and the state of those exported during 1994 is shown in table 1.3.

Table 1.3: Number of hides and skins processed locally and exported.

Type	Processed locally	%	Exported	%	Total
Hair skins					
Wetsalted	1 141 459	99.9	400	0.1	1 141 859
Drysalted	19 425	14.3	116 308	85.7	135 733
Total	1 160 884	90.9	116 708	9.1	1 277 592
Wool skins					
Wetsalted	1 958 076	99.1	18 664	0.9	1 976 740
Drysalted	1 657 516	34.7	3 121 257	65.3	4 778 773
Total	3 615 592	53.5	3 139 921	46.5	6 755 513
Hides					
Freshly flayed	588 186	100	-	-	588 186
Wetsalted	1 531 590	87.9	209 959	12.1	1 741 549
Drysalted	20 959	13	140 516	87	161 475
Dry	-	-	44 488	100	44 488
Total	2 140 735	84.4	394 963	15.6	2 535 698

Source: Sweetnam, 1995

The case of finished leather goods is a completely different story. One of the major threats to the leather industry in this country at present is cheap imports, mainly from China, Pakistan and India, of semi-processed and finished leather goods. The main reason for their low cost is the low labour costs under which the leather industries in those countries operate. The effect is already being felt with Sunderland, a tannery supplying the footwear industry having to close down at the end of 1995 as a result, in part, of the increased importation of cheap leather shoes. This problem can be further illustrated if one looks at the rise in leather shoe imports over the last 3 years[1].

Although figures are only available up until July 1995 it is possible, if one compares them to the corresponding period in 1994, to see that the trend of increased imports is both continuing and worsening from the point of view of the South African leather and footwear industries.

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[1] Figures prior to 1992 are not available

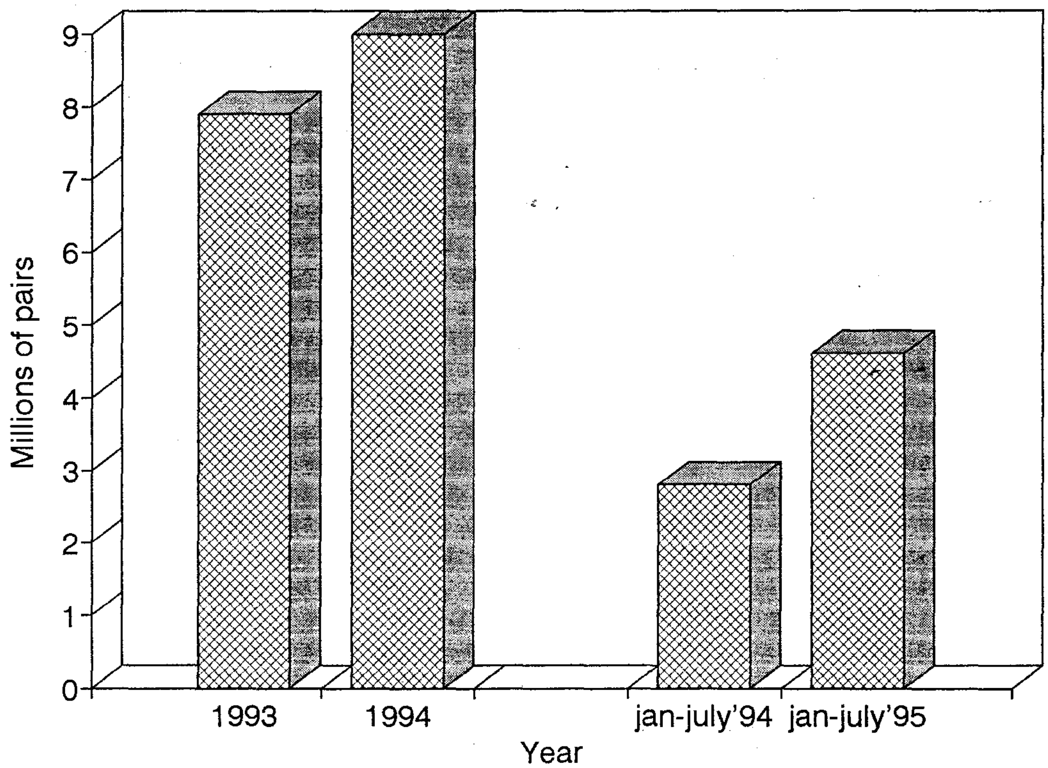


Figure 1.5: Imports of leather shoes: 1993-1995

Source: Dods, 1995

The problem is not however restricted only to leather shoes. It includes all finished leather goods. This can be illustrated by figure 1.6. which shows the value, in nominal terms, of all finished leather products imported for the period 1988-1994.

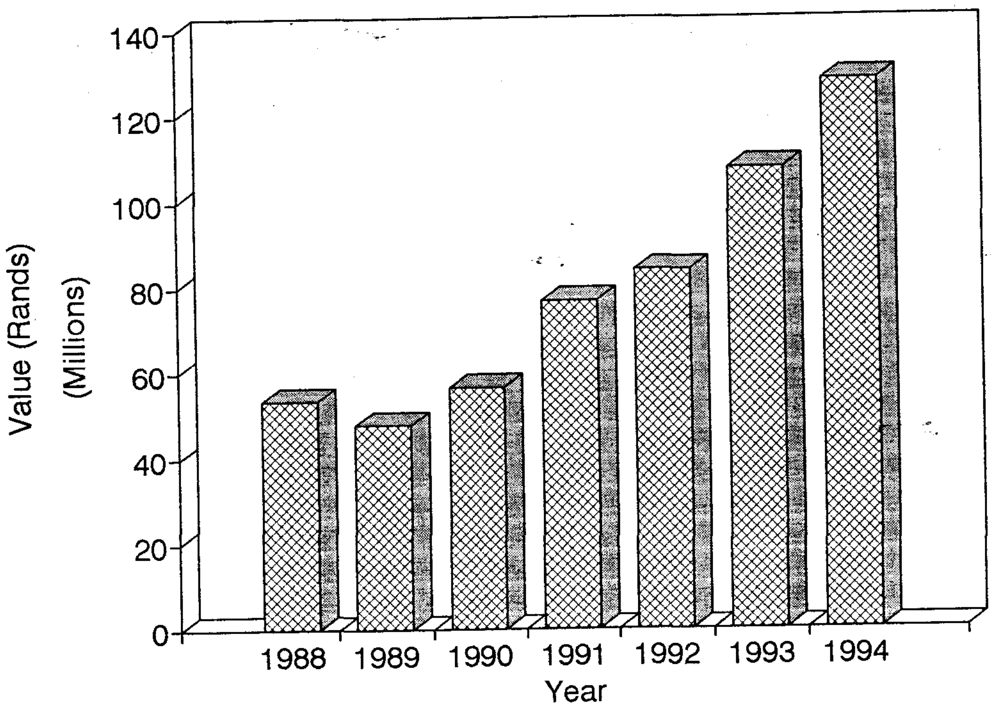


Figure 1.6 : South African imports of leather goods: 1988-1994

Source: Swanepoel, 1995

A further problem facing the leather industry has been the 1993 deregulation of the abattoirs. This has resulted in a decrease in both the quantity and quality of hides and skins available. The reason for the decrease in the supply of raw materials is because whereas before deregulation all slaughtering had to, by law, take place at the abattoir, this no longer holds. This has resulted in a lot of livestock owners who are a long way from the abattoirs and/or who only have a small number of animals to slaughter, doing it themselves. In many cases this has lead to them discarding the hides and skins without making them available to the leather industry for processing (Jackson-Moss, 1995). The decrease in the quality of the hides and skins has come about because, in the cases where the hides and skins of animals not slaughtered at the abattoir but made available, are removed from the carcasses by people lacking the skill of those who performed this task at the abattoir. This has lead to an increase in the amount of damage done to hides and skins(Jackson-Moss, 1995; Mouton, 1995).

A potential problem facing the South African leather industry and one that has already confronted similar industries in the developed regions of Europe and the United States, is the threat of forced closure due to the environmental damage caused by the effluent generated by the leather industries production process. This has already lead to a number of firms having to close down in the above mentioned regions (Jackson-Moss, 1995; Rose, 1995)

To expand on the above point, the leather industry's production process generates a large amount of effluent, both in terms of strength and volume. The elimination of pollution in general can however only be achieved by not producing goods that generate waste. Hence to achieve zero pollution we would have to have no economic activity. Calls for no pollution thus appear illogical. Zero waste is an impossibility, but quantities of waste that do not affect the environment is less fanciful because of the environment's assimilative capacity for accepting waste (Pearce and Turner,1991:64). If the amount of pollution discharged is less than the assimilative capacity of the environment, then in the long run no damage would occur. It is when the wastes discharged exceed the assimilative capacity of the environment that pollution and environmental degradation arises. The level of waste discharged therefore needs to be controlled to an optimal level.

This study is narrow in scope in so much as it does not go into the complex debate about what the optimal level of pollution is, nor does it try to value the economic and environmental costs and benefits of varying degrees of pollution. While these aspects are important they do not fall within the scope of this study. Furthermore, the assimilative capacity of water will differ from source to source. This should result in the price of economic incentives differing from one location to another. Unfortunately, at present in South Africa, these different assimilation capacities are not yet known. In this study it was decided to use a single standard for discharge for all water sources (a point taken up in Appendix D following Chapter 6).

Environmental economic theory claims that the most economically efficient and equitable means of reducing pollution to some predetermined level is through the use of economic incentives as opposed to a system of standards or so called "command and control" techniques (Seneca and Taussig,1974; Baumol and Oates,1988; Pearce and Turner,1991). By equitable it is meant that the cost of the externality caused by the production of a good be borne by the producers and consumers of that product. This would include not only the cost of the damage caused by pollution, but also the costs of the development, installation and use of pollution abatement equipment.

The aim of this study is to see whether the promise offered by environmental economic theory holds by applying the theory to a practical situation, namely controlling the effluent generated by the leather industry to some predetermined level.

It must however be noted that this study looks at two hypothetical leather firms discharging effluent into a hypothetical body of water. It does not therefore take into account the interaction, especially in terms of the trading of market permits, amongst all firms in all industries. This would entail the collection of an incredible amount of data and is not feasible for an undertaking of this nature. Approaches such as the so called "bubble technique", where a number of firms within a particular area trade permits amongst themselves, are therefore explicitly ignored. It is, however, felt that this will not distract from the objective stated above.

The study sets about testing the theory by first examining the leather industry's production process to ascertain what effluents are generated. This is followed by an in depth look at what environmental economic theory has to say on the control of industrial effluent discharge in general. This is extended to look at the theoretical costs and benefits to an individual firm if they undertook to treat the effluent that they generate. Data on the cost and effectiveness of treatment of leather firms is applied to the theory to see whether it holds in practice. The study concludes by making some recommendations on controlling the effluent generated by industry in general and the leather industry in particular.

CHAPTER 2 LEATHER FIRMS' PRODUCTION PROCESS AND EFFLUENT GENERATION

2.1 Introduction

In this chapter the process that hides and skins go through from the time that they are removed from the animals to the end of the production process is outlined. The reason for this is twofold. Firstly, to show a typical production process. Secondly, and more importantly, given that one of the main aims of this study is to investigate the control of pollution generated by the leather industry, to show where, how and what pollutants the leather industry's production process generates.

The leather industry can be divided up into tanneries, fellmongers and wet-blue tanneries. Tanneries take in raw and semi-processed animal hides or skins and convert them to a stable, usable end product. Fellmongers take in "raw or semi-processed sheepskins and use chemical processing to separate the wool or hair from the skin, which is then passed to a tannery for further processing." Wet-blue tanneries process raw hide to the "chrome (tanning) stage." At this stage the hide is "stable and can be stored or transported for final processing to leather elsewhere. Because of this function, wet-blue tanneries are normally found close to the source of hide supplies"

(WRC, 1987:10).

The leather industry in South Africa processes around two million hides and consumes approximately 600 000m^3 of water per annum. Most of this water becomes effluent (WRC, 1989: 1), because the bulk of the water usage is of a "non-consumptive nature, apart from relatively minor losses due to evaporation, steam generation and moisture held up in the final product" (WRC, 1987: 13). Therefore the total amount of effluent generated by the leather industry is very close to the total amount of water used (i.e.600 000m^3 per annum). This effluent is generated within the tannery or fellmongery from those steps in the production process involving water addition. The next section outlines the production process.

2.2 Manufacturing or production process.

The processing steps involved in tanning and fellmongering in South Africa vary in detail and in the point of termination which is dependent on the degree of leather processing carried out (WRC,1987:10). The following main operations will however cover the whole process - curing of hides and skins and tanning - and gives an indication of the types of effluent generated at each stage of production.

2.2.1. Curing of hides and skins

The curing process prevents the organic degradation of hides and skins from the time they are removed from the animals to the start of the tanning process. This time period can be between a few hours and six months. Several types of curing are practised. These include:

(i) short term cures (up to three weeks) which involve cooling and/or chemical curing; and

(ii) long term cures (up to six months) which involve either drying, dry salting, wet salting or stack salting.

2.2.2 The tanning process

(a) Soaking

"Hides and skins are washed to remove blood and dirt. In the case of salted hides a major proportion of the curing salt is removed. For dry hides a soaking agent is normally added to accelerate the wetting back process. The effluent from the soaking process has high organic levels.

(b) Unhairing

After soaking, the hides or skins are drummed or paddled in a lime sulphide solution to remove the hair and epidermis and to open up the fibre structure for the subsequent penetration of the tanning materials. The effluent from the unhairing process has a high solids content consisting of degraded protein and hair, surplus lime and sulphide, with high pH, permanganate value (PV) and chemical oxygen demand (COD) values.

(c) Fleshing

From the unhairing drum the hides are fleshed by machine to remove fatty tissue on the flesh side. The sludge from this machine consists of fatty tissues, hair, protein matter and sulphide compounds.

(d) Delime and bate

The hides are floated in warm water and delimed with ammonium salt and/or weak acid to bring the pH value to approximately 8,5, suitable for the bating enzymes, which clean up the grain surface of degraded material resulting from the unhairing process. The effluent contains ammonium and calcium salts and degraded protein matter.

(e) Chrome tanning

The delimed and bated hides are then pickled in a solution of sulphuric and formic acids and sodium chloride followed by the addition of the chrome tanning salts. The spent liquor contains chromium and other salts which can be recycled to minimise chromium and salt in the effluent and to reduce costs. However, it is not possible to drain all the spent liquor from the drum and the subsequent washing process gives rise to some chromium in the effluent.

(f) Wet-blue

At this stage the hides may be washed and partially dewatered, giving rise to a stable marketable product known as wet-blue.

(g) Neutralising and Retanning

After thinning operations the wet-blue stock is washed and neutralised with a solution of mild alkali to bring the pH up to about 4,5, suitable for retanning. A wide range of retanning agents are drummed into the leather comprising vegetable tan, synthetic tans and synthetic polymers. The effluent has a high dissolved solids content.

(h) Dyeing and fatliquoring

After retanning the hides are refloated in warm water, dye is added and drummed into the leather, followed by the addition of an emulsion of fatliquoring oil. The effluent contains spent dye-stuff and oil.

(i) Samm/Setting

A comparatively small amount of effluent is generated during the mechanical samm (a process which squeezes out excess moisture from the hides) and setting (a process which removes wrinkles and flattens the leather surface) operation. This contains low concentrations of spent dye-stuff and oil.

(j) Vegetable Tanning

Because of the high oxygen demand of vegetable tannins, every effort is made by tanners to reduce these in the effluent. Where light-weight vegetable tanned leathers are produced a minimum of vegetable tanned extract is used in a drum process. The delimed hides are drummed or suspended in pits in a polymeric sodium hexametaphosphate and sulphuric acid solution which can be used repeatedly with topping up. This is followed by immersion in an initial weak tan liquor, some of which is discarded to maintain the purity of the subsequent strong liquors circulating at a warm temperature in a series of pits. After tanning the leather is washed followed by bleaching and filling. These effluents contain spent vegetable tans.

(k) Finishing

Finishing is the application of a coating or coatings to the leather surface, to impart specific effects and properties (colour, scuff resistance, etc). Finishing processes vary according to the end product and, if properly managed, should not produce significant quantities of effluent" (WRC, 1989: 3-5).

In summary, the final raw tannery or fellmongery effluent is characterised by "high levels of organic materials (proteins and fats), suspended solids and dissolved solids. Depending on the particular factory operation and curing process, the final effluent will include other pollutants such as soil, antiseptics, salt, chrome, vegetable tannins, syntans, dyes and lacquers in varying quantities" (WRC, 1987: 13). Table 2.1 gives a break down of typical gross pollutant characteristics of raw effluent from tanneries and fellmongers.

Table 2.1: Typical gross pollutant characteristics of raw wastewaters from South African tanneries and fellmongers.

Effluent concentration mg\l	Chrome tannery full finishing	Wet - blue tannery	Chrome and vegetable tannery full finishing	Fellmongery
pH	9 - 11	9 - 11	9 - 11	9 -11
COD (000)	7	10 - 20	6	4
SS (000)	2 - 4	5 - 10	2 - 5	2 - 5
TDS (000)	15 - 20	20	10 - 15	10 - 15
Sulphide	100	500	300	700
Chromium	100	350 - 500	500 - 600	0

Source: Adapted from WRC, 1987: 14

Notes: 1 COD - Chemical oxygen demand

2 SS - Settleable solids

3 TDS - Total dissolved solids

[See figure A.1 in appendix A for a more detailed account of the process additives and effluent characteristics arising from typical leather processing operations].

From the table it can be seen that in terms of pollution load, wet-blue processing is responsible for the majority of the load discharged by a full tannery while certain post-chrome tanning operations also generate considerable pollution loads (WRC, 1989: 10).

According to Anderson (1977:95) if we were to use only one variable to indicate the health of a body of water, it would be the dissolved oxygen content. This is because oxygen is crucial for most life forms that are to be found in water.

The major effect of most pollutants on water quality is the reduction of dissolved oxygen caused by the "biochemical oxidation of organic matter" (Anderson,1977:96). The higher the chemical oxygen demand (COD) value of effluent, the greater the amount by which it reduces the amount of dissolved oxygen available in a body of water and the greater the detrimental effect on the life within that water.

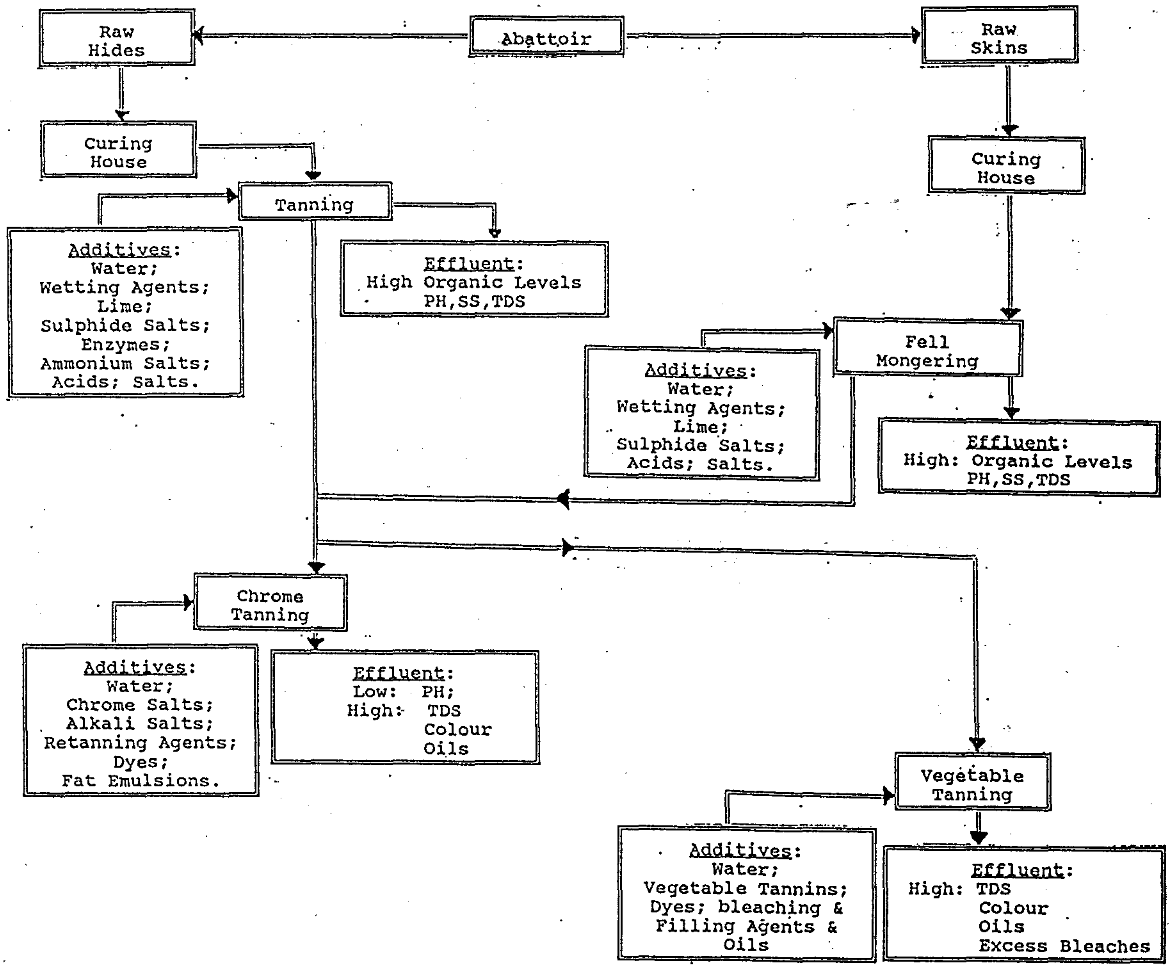
"Suspended solids reduce the amount of light available for plant growth." It may further serve as sites for bacterial activity (Anderson,1977:97). High levels of elements such as chrome and sulphide would be toxic and thus have a detrimental on life within a body of water.

The effluent that has been generated by the leather firm has to be disposed of. In South Africa this has been done either by discharge to facultative lagoons or evaporation ponds and\or by spray irrigation of settled wastewater to land and\or by discharge to municipal sewers (WRC, 1989:14).

In this study only the option of discharge to municipal sewers is going to be looked at. The rationale behind this is that firstly, the requirements regarding the disposal of wastewater to land is being tightened up due to soil degradation and ground water pollution problems and is not a "preferred disposal route in the policies advocated by the Department of Environmental Affairs, particularly where a viable alternative route exists." Secondly, the disposal to pond systems is not very favourably viewed by the authorities because sludge disposal and odour problems eventually arise in all ponding systems (WRC, 1989:15 and WRC, 1987:17). Therefore discharge to sewer is becoming an increasingly essential part of tanning practice. An assumption is therefore made that the only option available to leather firms for the disposal of effluent is by discharging into municipal sewers.

What this study is essentially interested in is the control of the disposal of this effluent. The next chapter therefore looks at what environmental economic theory has to offer by way of controlling the pollution generated by industry.

APPENDIX A



Notes 1. SS = Settleable Solids
2. TDS = Total Disolved Solids

Figure 2.1: Typical leather processing operation in tanneries and fellmongers showing process additives and effluent characteristics.
Source: Adapted from WRC, 1987:12

CHAPTER 3 THE ECONOMIC THEORY OF POLLUTION CONTROL

3.1. Introduction

In the previous chapter we looked at the leather industry and in particular at the type and amount of pollutants generated in the production of leather. In this chapter the theoretical framework of the economics of pollution control is presented.

There are a number of ways of controlling pollution. These include moral suasion, education, environmental bonds, command and control techniques and economic incentives. This chapter however concentrates only on the latter two. The reason for this is that although the others do have a part to play in the control of pollution, command and control are by far the most widely used (Anderson, 1977; Hahn, 1989 and Cropper and Oates, 1992), while economic incentives offer the greatest potential for use (Atkinson and Tietenberg, 1987; Lyon, 1989 and Pearce et al, 1989).

It should be noted that throughout the thesis the term "charges and taxes" are used. In the literature these are often used interchangeable as they are in this thesis. There is therefore no difference between the two terms

The chapter starts by describing what command and control techniques entail and goes on to discuss their advantages and disadvantages. In section 3.3 economic incentives are introduced. The incentives examined are charges and taxes, subsidies and marketable permits. Furthermore there is discussion on how each type works and their advantages and disadvantages.

3.2. Command and control

Controlling pollution by making use of command and control methods involves "a directive to individual decision makers requiring them to set one or more output or input quantities at some specified levels or prohibiting them from exceeding (or falling short of) some specified level. If the activity levels satisfy these requirements, they are considered legal and no penalty is imposed. However, if they are violated, the individual is considered to be a law breaker who is subject to punishment" (Baumol & Oates, 1988 :191).

There are disadvantages involved in using command and control measures. Firstly, they are not an economically efficient means of pollution control because polluters are not allowed the freedom to decide how best to control the pollution that they cause, for example, by having the authorities specify the abatement techniques to be used (Baumol & Oates, 1988 :1). Furthermore, reduction of pollution is not done at a minimum cost to society (Cropper and Oates, 1992:686; Pearce et al, 1989:162). There is also no incentive for firms or individuals to reduce their pollution below the stipulated level or to develop new pollution abatement technology (Downing and White,1986:18-29; Milliman and Prince, 1989:247-265). Secondly, they are not equitable means of pollution control because the burden of research and development costs into new technology lies with the state (and hence the taxpayer) rather than with the polluter (Cairncross, 1989:9). These disadvantages are looked at in more detail below.

The first disadvantage, that command and control techniques are not an economically efficient means of pollution control, can be illustrated with the aid of an example. Where a standard for compliance is instituted, the regulating authorities inform the firms of the appropriate reduction in pollution required to meet the standard. If all firms, regardless of their individual costs of control, are required to limit pollution by the same amount, the pollution reduction will not be done at a minimum cost to society.

Consider an industry which consists of two firms (firm 1 and firm 2) each generating a similar output of pollution. An environmental authority now requires the output of pollution by the industry to be cut by half. The regulator tells each firm to cut its output of pollution by 50%, ***"regardless of any underlying cost differentials between the firms"***, an equal quota of 50% of pollution output would have to be reduced by each firm. Accordingly firms 1 and 2 incur a cost to meet their respective quotas (Seneca and Taussig,1974:225). "This may however constitute a very expensive way of achieving the desired result, if for example, at current levels of output, the marginal cost of reducing output of pollution for firm 1 is say one-tenth that of firm 2. It would be expected to be much cheaper for the economy as a whole to assign firm 1 a much greater decrease in pollution emissions than firm 2" (Baumol and Oates,1988:164).

"With full knowledge of the relevant cost functions, the across-the-board quota" could be altered so that each firm is given a separate pollution reduction quota. "The objective of individual quotas would be to correct for the inefficiency implicit in assigning an across-the-board quota, when pollution reduction cost functions differ between sources" (Seneca and Taussig,1974:226).

Thus, in this example, costs could be minimised if firm 1 increased its levels of pollution reduction above 50% and firm 2 lowered its amount of pollution reduction below 50% "until the marginal cost of pollution abatement for each firm is equal. The costs associated with this distribution of pollution reduction quotas are minimal with respect to any other division of the target between the firms. Therefore individually assigned quotas can restore efficiency to a regulatory policy" (Seneca and Taussig, 1974: 226).

"However, the obvious difficulty of achieving the least cost solution is that complete information is required for each cost function. In the above example, it would mean obtaining the technical cost information for the two sources of pollution. As the number of pollution sources are expanded beyond two, the required information for an efficient regulation policy increases. This has obvious implications in terms of the cost of gathering and analysing such data, the required bureaucratic machinery to administer individual quotas, the necessary monitoring of compliance and of course the subsequent use of enforcement procedures, if necessary. Such considerations tend to make an efficient regulatory policy extremely cumbersome and costly. Accordingly, the efficiency gains of moving from an across-the-board policy of equal pollution reduction to individually assigned pollution quotas may be offset by the enormous increase in costs associated with formulating and implementing an efficient regulatory policy" (Seneca and Taussig, 1974: 227).

Another disadvantage is that command and control measures do not give firms any incentives to develop new pollution abatement technology or to reduce their pollution below the stipulated level. If the polluter discharges less than the limit he will not be rewarded. If he discharges 1 or 100 less units of pollution his position will be unchanged. There is also therefore no incentive for a polluter to decrease his pollution discharge below the legally required limit. By requiring that firms install the "best available" technology, the burden of the costs of research into new pollution abatement technology rests with the state. It would be more efficient and equitable to have these costs rest with the polluters.

There are, however, some advantages to using direct controls. They are best suited for a crisis situation i.e. where a species or life support system is severely endangered. Use of the resource can be totally prohibited or severely curtailed within a very short period of time. The command and control approach avoids completely the problem posed in setting a charge or using marketable permits because no attempt is made at searching for an optimum so there will be none of the cost involved if an environmental authority inadvertently sets the charge too high or too low.

As has been shown, one way of trying to stop environmental degradation is to use command and control techniques, but this approach has a number of shortcomings, namely they are not economically efficient or equitable. Economic incentives provide a way through this problem. They are discussed in the next section.

3.3. Economic incentives

An alternative to command and control techniques in controlling pollution is the use of economic incentives. "Economic incentives attach a cost which is determined either by the authorities or by the market, to polluting activity. This cost is related to damages suffered as a result of the externalities resulting from the acting parties' activities" (Baskind and Stauth,1992:41). According to Anderson (1977:21) "it has as its primary purpose the establishment of new markets that efficiently allocate environmental resources. It is the lack of such markets that are a major cause of environmental problems. Manufacturers dump raw wastes into the air and water without regard to the high social costs of such actions, not because they are bad people, but because it is economically advantageous for them to do so. The use of other resources (eg. capital and labour) are subject to market prices and constraints while the use of many environmental resources are not."

If environmental resources were priced, the prices "would indicate their opportunity cost." This in turn would affect a whole complex of decisions about their use. For example, "it may affect the design of industrial processes, the kinds and amounts of raw materials used, the nature of the final products produced, the modification of pollution streams" and the amount of treatment and recycling done (Anderson 1977,28). "Resources would be used in a way that produced a net benefit for society instead of being destructively overused" (Anderson 1977,28).

There are a number of advantages in using economic incentives instead of command and control methods to protect the environment. Economic incentives can be shown to be more economically efficient. They do not interfere directly in the internal operations of entrepreneurs and greater flexibility is allowed in meeting environmental objectives. Firms for whom the cost of limiting environmentally damaging activities is lowest will do so first or to a greater degree than those whose cost of controlling pollution is greater (Pearce et al, 1988:161; Cropper and Oates, 1992:686).

Because economic incentives attach a cost to all pollution, they act as a continuing incentive to all firms to reduce emissions which in turn acts as a stimulus for the development of more efficient and less costly technologies(Milliman and Prince, 1989:247-265). For this reason they are an equitable means of pollution control because the cost burden of research and development rests with the polluter rather than the state. There are a number of economic incentives that could be used including taxes and charges, subsidies and marketable permits, each of which will be examined in more detail below.

3.3.1. Taxes and charges

"A pollution charge serves to attach a cost, determined by the environmental authorities, to the polluting activities of individuals and/or firms. This cost is related to the damage caused as a result of the individuals or firms actions. They should ideally result in environmental quality meeting the goals set by the authorities" (Baskind and Stauth,1992:41).

If a firm is charged for every unit of pollution that it discharges into a environmental medium, then it will have to "internalise the previously external costs associated with its waste disposal, as it will have to pay a certain Rand amount for each unit produced. The theoretically correct level of such an effluent charge is the per unit external cost of the untreated pollution discharge of the firm" (Seneca and Taussig, 1974: 80). This can be illustrated with the aid of figure 3.1.

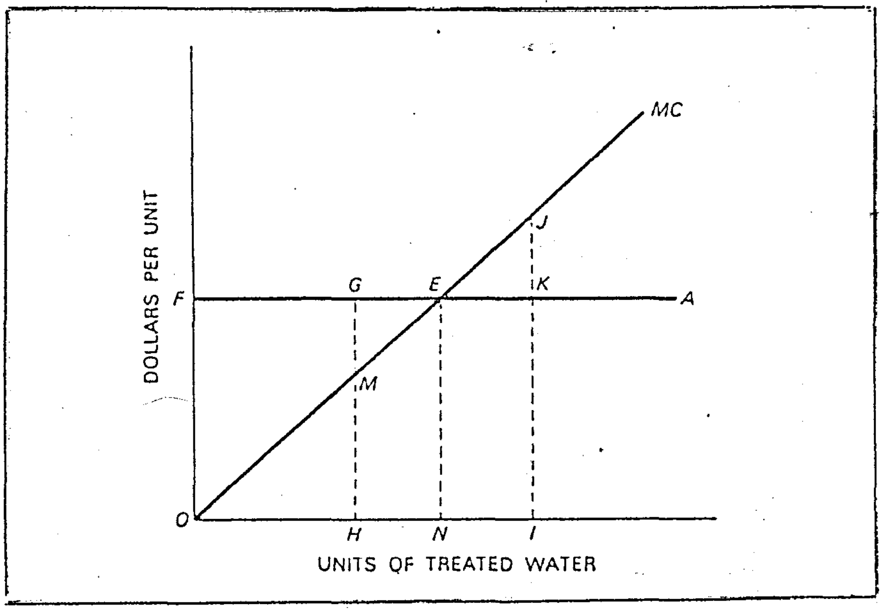


Figure 3.1 : A clean water market.

Source : Seneca and Taussig, 1974: 74.

Assume that the government knows the external cost of each unit of pollution discharged by the firm into a body of water and that it amounts to "OF" Dollars per unit of discharge. The government can charge the firm "OF" Dollars for each unit of untreated water that it discharges. "The horizontal line "FA" will then represent the (constant) costs of a unit of untreated water to the firm" (Seneca and Taussig, 1974: 80).

"The effluent charge thus becomes an internal cost to the firm, exactly like the costs of labour, capital and all other factor inputs in the production process. The firm is induced to make profit and loss calculations to determine its best response to the imposition of the effluent charge" (Seneca and Taussig, 1974: 80). One alternative open to it is to treat its wastes, incurring the marginal treatment costs given by the marginal cost schedule in figure 3.1.

Another alternative open to the firm is for it to continue discharging untreated water and paying the resultant charge (i.e. "OF" Rand per unit of discharge). "The profit maximising (or loss minimising) solution for the firm is to treat the water until the cost of treating one more unit would exceed the effluent charge it pays per unit for the discharge of untreated water" (i.e. treats "ON" units of water in figure 3.1) (Seneca and Taussig, 1974: 80). At all treatment levels less than "ON", the firms total costs can be reduced by further treatment. At all levels of treatment beyond "ON", the costs to the firm of treatment are greater than the cost of discharging untreated water and paying the resultant charge. "Therefore, "ON" is the profit-maximising treatment level for the firm, given the "OF" level of the effluent charge" (Seneca and Taussig, 1974: 81).

The setting of the correct level of effluent charges is a very complex issue because large informational difficulties exist when we attempt to measure the true marginal benefits and cost functions which "mitigates against the likelihood of selecting the socially optimal charge" (Seneca and Taussig, 1974: 227). Despite these difficulties it is still possible to use a system of charges to obtain a practical and efficient procedure by reaching a social agreement on some "overall target of environmental quality" (i.e. an agreement by all relevant stakeholders on what would constitute an "acceptable" level of pollution). Thus a rough idea of the required reduction in pollution can be obtained and a "viable policy" implemented (Seneca and Taussig, 1974: 228).

The environmental authority sets a charge in order to reduce the output of pollution to the predetermined level. If this initial charge was set higher than the theoretical optimum, the resultant reduction in pollution would be greater than the predetermined level. "In such a situation the signal will be to lower the charge." Conversely, if the initial charge is set below the theoretical optimum, the "achieved waste reduction will fall short of the desired amount and this would indicate that an increase in the charge is necessary. Thus by adjusting the effluent charge an efficient least cost solution will be obtained consistent with the desired waste reduction target" (Seneca and Taussig, 1974: 228)

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The method suggested for setting charges, i.e. setting a charge, observing the results and then adjusting the charge if necessary, is not costless. It means that some of the polluting firms will have to "modify their operations" as charges are adjusted (Baumol and Oates, 1988: 163). For example, the regulating authority may set a charge and firms will respond by installing pollution abatement equipment. If it is then found that the charge has been set too low and is raised, polluting firms may have to purchase new pollution abatement equipment if the previous equipment is found to be inadequate (Anderson,1977:35).

"At the very least, firms should be warned in advance of the likelihood of such changes so that they can build some flexibility into their plant design" (Baumol and Oates, 1988: 163). Most sources are able to adjust their treatment levels, within a limited range, without a substantial change in costs. This is because for a given control strategy, a range of controls is possible with a given level of capital investment. "Thus a firm that has installed a treatment system in response to a given charge will probably not need to scrap the system to increase its treatment level if the charge, and therefore the amount of treatment, is raised by a small amount" (Anderson, 1977:35).

"Mathematical models of river basins or air pollution regions can be used to estimate the impact on environmental quality of various discharge levels at different sources in the area." The needed cost data can be obtained by "estimating average data for different classes of discharge" from different sources in an area (Anderson, 1977:35). "Experience might soon permit the authorities to estimate the charge levels appropriate for the achievement of a target reduction in pollution with more accuracy" (Baumol and Oates,1988:163)

"A charge presents a person or firm engaged in an environmentally damaging activity with an immediate incentive to control it, because the activity itself creates a financial liability that cannot be avoided by delaying payments or putting off adopting control measures. The source can legally reduce the liability only by taking steps to reduce the discharge. There is no delay pending completion of enforcement actions before an incentive to cut back on the polluting activity exists" (Anderson, 1977: 34).

"The charge approach leaves the question of control techniques and technology to the discharger." This provides an incentive for dischargers to find cheaper and more efficient means of pollution abatement (Anderson,1977:34). "Regulations, particularly those which specify control equipment, tend to lock polluters into technologies which may not be the most effective or cost efficient, and the burden for technical advance reverts to the environmental authority leading to an expansion of the environmental bureaucracy" (Baskind and Stauth,1992:42).

"The imposition of a charge may meet with political opposition from acting parties since a previously "free" activity now carries a cost, but it may be welcomed by the affected parties and favoured by a financially constrained environmental control agency. The polluter pays for costs presently being borne by society and income is generated for rather than expended by the environmental authority" (Baskind and Stauth,1992:42).

In the next section subsidies are examined in order to ascertain whether they are equivalent to charges.

3.3.2 Subsidies

Theoretically the payments of a "per unit subsidy by the environmental authority to the polluter for abatement leads to the same outcome as the imposition of a charge" (Baskind and Stauth,1992:42).

The environmental authority could offer a subsidy (equal to an effluent charge) "per unit of waste not discharged." Firms would reduce wastes to the same level that they would under an equivalent charge because it is "profitable to do so." The environmental authority could increase or decrease the amount of abatement that firms undertake by increasing or decreasing the size of the subsidy. Thus we can see that the reduction of waste emissions is the same as it would be if we used a charge (Seneca and Taussig, 1974:222).

There are however a number of disadvantages involved in using subsidies. Some bench mark would have to be set for each firm so that its reduction in damages can be estimated. It is not inconceivable that a firm may start off polluting more than it would otherwise have in order to qualify for larger subsidy payments (Baskind and Stauth,1992:43).

There is also less of an incentive for firms to develop new pollution abatement technology under a system of subsidies than under a system of charges. "Consider a firm evaluating a pollution reduction innovation. If the introduction of the new innovation is likely, at some future time, to induce the environmental authority to reduce fiscal incentives, then the change in fiscal incentives would take the form of a reduction in the future rate of payments from the authority and so reduce the profitability of the innovation" (Baumol and Oates, 1988:212).

"A charge increases the polluting firms costs of production which in turn influences the polluting industry's profitability. This will discourage entrepreneurs from entering into the environmentally damaging industry and decrease outputs of existing firms." It may even cause some firms to exit the industry. On the other hand polluters will attempt to "use subsidies to maximise profits so increasing the industry's profitability and attracting others into the polluting activity" (Baskind and Stauth,1992:43).

The use of subsidies will discriminate against firms who have already taken action prior to the imposition of the subsidy relative to those firms who have not. Since subsidies are usually financed from general taxation, this "spreads the costs of abatement across all taxpayers rather than returning it to the polluter. It also utilises scarce government funds for pollution control"

(Baskind and Stauth,1992:43).

It should be noted that while the short run pollution reduction results at the level of the firm may be equivalent when either charges or subsidies are used, the same does not hold for an industry in the long run (see for example Baumol and Oates, 1988, Chapter 14).[2]

We now turn to marketable permits as another type of economic incentive.

[2] I am grateful to Mr Banach of the Department of Economics at the University of Natal (Pietermaritzburg) for bringing this point to my attention.

3.3.3. Marketable permits

In this section we first look at how marketable permits work and then go on to compare them with a system of charges. Marketable permits define property rights for environmental resources. The environmental authority creates a limited number of permits for the discharge of a specific air or water pollutant which are then allocated to polluters. Environmental authorities can directly limit waste dischargers to their target levels by restricting the quantity of permits issued. As a market for the permits develops a market clearing price will emerge that, like a fee, will indicate to polluters the opportunity costs of waste emissions. Since all sources face the same price for a permit, cost minimising behaviour results because marginal abatement costs would be equalised among these sources. It is interesting to note that the firms marginal abatement cost curve is in fact its demand curve for permits. This can be illustrated with the aid of figure 3.2.

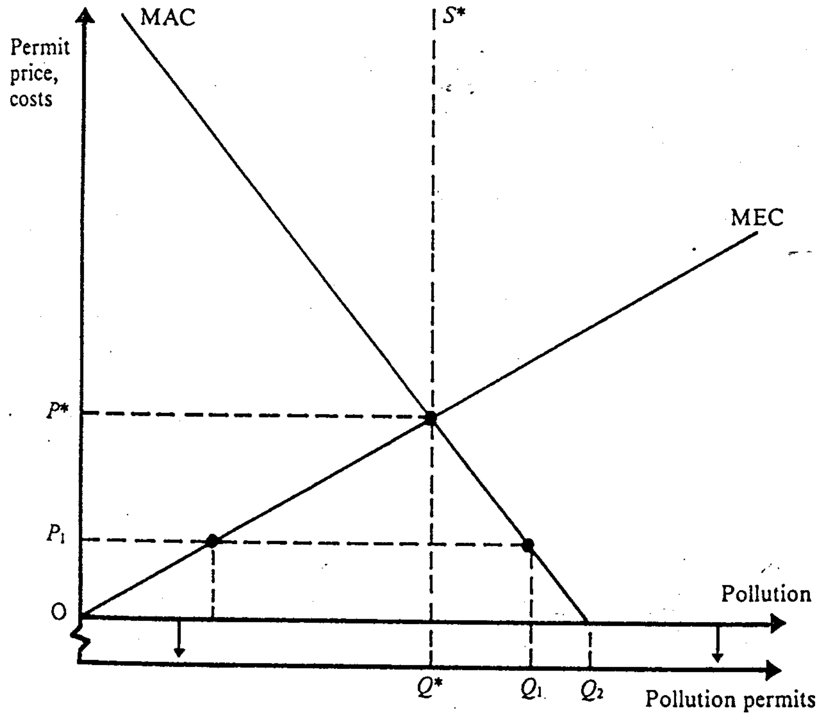

Figure 3.2: The basic analytics of marketable permits
Source: Pearce and Turner, 1991: 111

In figure 3.2 the supply of permits is regulated and assumed not to be responsive to price. "At a price of P1 the polluter will buy OQ1 permits." This is because it is cheaper "to abate pollution from Q2 back to Q1 than to buy permits. To the left of Q1, however, it is cheaper to buy permits than to abate pollution." The MAC curve is thus the demand curve for permits. The sum of the firm's marginal abatement cost curves is therefore the market demand curve (Pearce and Turner, 1991: 111).

Polluters with high abatement costs will prefer to buy the permits while low abatement costs polluters will sell permits in favour of abating pollution (Pearce et al 1989:165). Moreover, if the authorities wish to tighten standards they can "buy in" the permits themselves and reduce the number available, thus reducing the amount of pollution (Pearce and Turner, 1991:113).

When an environmental authority is designing marketable permits they need to decide on their duration. Permits that are of a long duration would tend to "encourage long term planning and construction of efficient facilities by polluters." On the other hand shorter duration of marketable permits would allow the authorities "greater flexibility in improving environmental quality by reducing allowable emissions, "without the agency having to bear the costs of re-purchasing of rights from dischargers or without having to simply confiscate rights, as is implicitly done when command and control regulations are tightened" (Lyon, 1989: 1304).

An advantage that marketable permits have over effluent charges is that they "promise to reduce the uncertainty and adjustment costs involved in attaining the required levels of environmental quality." As was discussed earlier, it is unlikely that the authorities would set the correct charge at the first attempt. It was however shown that through a process of trial and error, it was possible for the authorities to arrive at a charge that would ensure that the target levels of emissions were met. This process is not costless and is therefore an "unattractive prospect for administrators of the programme. Permits on the other hand, allow the authorities to directly set the total quantity of emissions at the allowable standard. There is, in principle, no problem in achieving the target" (Baumol and Oates, 1988:178).

A further advantage that a system of marketable permits has over effluent charges are the way in which they deal with the "complications that results from economic growth and price inflation. Continuing inflation will erode the real value of a charge. Similarly, expanding production of both old and new firms will increase the demand for waste emissions. Both of these will result in the charge being raised periodically if environmental standards are to be maintained." The authorities, under a system of charges, "are forced to choose between unpopular fee increases or non-attainment of standards." Permits however, respond to demand and supply. This would mean that if the supply of permits is kept constant, inflation and/or expanding production by firms, would "simply translate itself directly into higher prices" (Baumol and Oates, 1988:178).

Permits offer a continuing incentive for abatement, which is a major advantage (that it shares with effluent charges) over command control methods. They are economically efficient because the environmental goal will be met at minimum cost to society and equitable because the polluter pays for the damage caused.

"The initial allocation of permits is a thorny issue. Equity and political issues need to be taken into consideration" Baskind and Stauth,1992:43). There are two basic approaches to the initial distribution : government sales of marketable permit to dischargers, normally in the form of an auction, and a "free initial distribution followed by trading amongst the dischargers" (Lyon, 1989:1302).

"If the approach based on initial government sales worked efficiently there would be no need for exchanges immediately. Permit trading will, however, begin to take place if dischargers treatment costs change and/or as dischargers' enter and leave the region. In a well functioning market an approach based on free initial distribution should result in trading occurring until marginal costs are equated across polluters" (Lyon, 1989:1303).

"Where the incentive for such trading exists, buyers who can reduce emissions only at a higher real cost will be willing to pay more than the reservation price of the sellers, but there may well be significant search costs and elements of strategic behaviour that impede the transfer of emissions entitlements that are necessary to achieve the least cost outcome. In contrast, under a system of fees, no such transfers of permits are needed. Each source simply responds directly to the incentive provided by the fee" (Baskind, 1989:6).

As we have seen, controlling pollution through the use of economic incentives offers a number of advantages over using command and control techniques, namely, they are more economically efficient and equitable. Once environmental resources have been priced, the prices would indicate the opportunity costs of using environmental resources and would affect a whole complex of decisions about their use. The individual or firm is left with a number of options on what to do about the pollution that their particular production process is generating.

The individual or firm could change the inputs by substituting less polluting ones for some of those being used at present. This would affect the amount of pollution being generated. Another option may be to change the nature of the final products produced so that they require less of some polluting input. The firm or individual may modify their pollution streams so that the effluent generated is easier to treat or control. It may be worthwhile for the polluter to build a treatment plant or to recycle some of the pollution generated.

Which option is chosen will depend on their relative costs and benefits. In the next chapter a framework is developed to help ascertain what the costs and benefits are of some of the options available to a leather firm and whether it is economically viable for a firm to pursue any of them.

CHAPTER 4 THE THEORETICAL COSTS AND BENEFITS OF TREATMENT FOR AN INDIVIDUAL FIRM

4.1 Introduction

From chapter 3 it can be seen that no matter what form of effluent control is used, it would entail some treatment on the part of the firms. This chapter therefore looks at a treatment plant in order to illustrate what a treatment process can entail.

Furthermore, chapter 3 illustrated the theoretical economic gains accruing to society by controlling pollution through the use of economic incentives rather than by using a system of standards. This chapter examines the theoretical costs and benefits accruing to an individual firm when it undertakes treatment. The question of how much treatment a firm should undertake is addressed by using a formula which has been developed to aid firms with this decision.

4.2. A treatment process

The treatment process outlined below, and represented diagrammatically in figure 4.1, is an example of one of a number of different types of processes available to the leather industry for the treatment of effluent. It is based on a pilot waste water treatment plant designed by LIRI Technologies and is included here only to illustrate what a treatment process can entail.[3]

Three streams of effluent are discharged from the tannery. They are made up of:

a neutral stream (1),

an acidic (chrome) stream (2)

and an alkaline (lime) stream (3).

All three streams pass through a rotary screen (4) where they are screened individually in order to slow down the rate of discharge. From the rotary screen they go to flow balancing sump(5) where they are kept before being pumped, at a controlled rate, to the treatment plant.

The neutral stream is pumped into another flow balancing sump(6). Chrome is pumped into a mixing flocculation tank (7) where other chemicals are mixed with it to precipitate out the chrome. All of the acidic effluent is then pumped into a settling tank (8) where the chrome settles out. The sludge goes to a acidification tank (9) where sulphuric acid is added to it. This converts the chrome sludge back into chromium sulphate which is recycled to the tannery for re-use. Chrome free supernatant from the settling tank is returned to the flow balancing sump(6). Lime Sulphate is pumped into a fat trap\settling tank (10) where fat, oil and grease are skimmed from the surface. Settleable solids sink to the

[3]For further information on treatment plants see WRC, 1987:88-120.

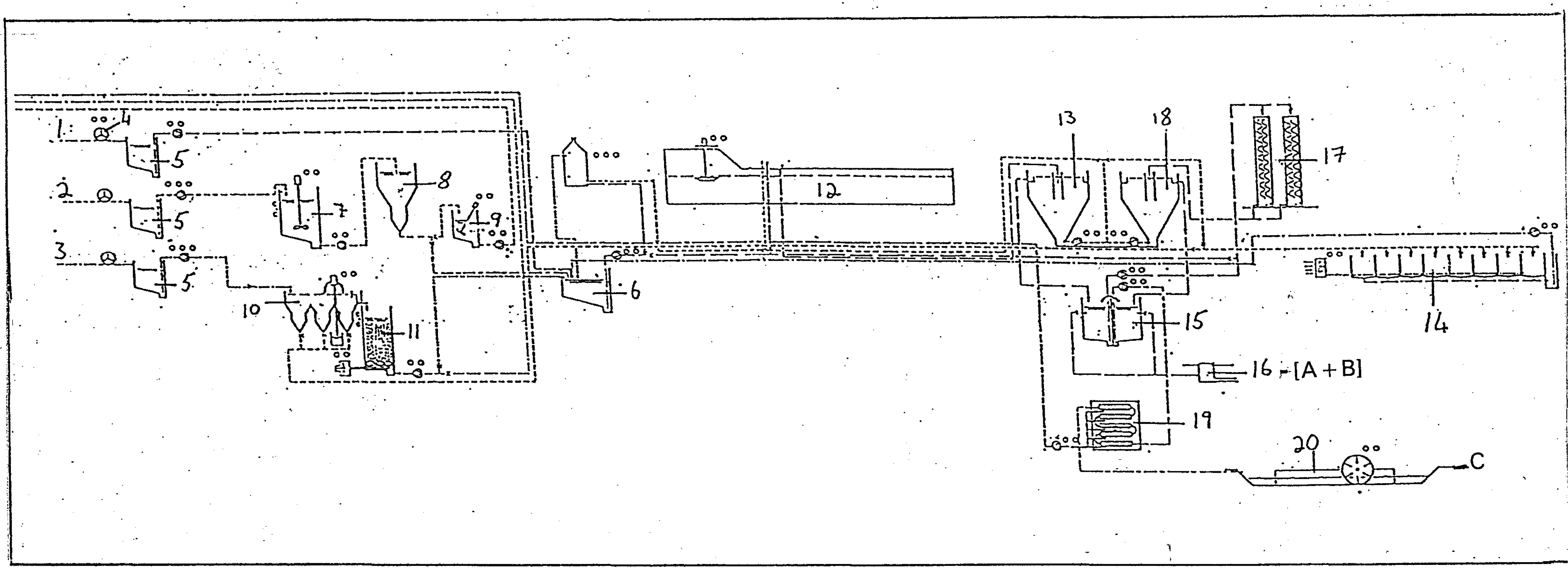

Figure 4.1: Flow diagram for pilot wastewater treatment plant

Source: Rowswell, 1995

bottom. The effluent in the fat trap\settling tank runs into another flocculation tank (11) where sulphur oxidisation takes place and lime sulphate is recycled back to the tannery. The lacquer goes to the flow balancing tank (6). Sludge from the fat trap\settling tank (10) is discharged to drying beds for de-watering (14).

The effluent in the flow balancing sump is pumped into an oxidisation ditch (12) where it is aerated to keep it aerobic before being transferred to a settling tank (13) for removal of humus sludge. A small percentage of the effluent in the settling tank is recycled to the oxidation ditch to re-inoculate new effluent with micro-organisms. The rest is discharged to drying beds. Supernatant from the settling tank flows to a sump (15) between settling tanks and sewerage disposal. From here it can either be discharged to sewers (16) **[A]** or undergo additional treatment, which would involve it being pumped to bio-filters (17) where further nutrient removal takes place. From the bio-filters the effluent is transferred to a second settling tank (18) for removal of additional humus sludge before discharge. The sludge from this second settling tank is pumped to drying beds. What is in the drying beds can be used as fertilizer.

Effluent from the settling tanks (18) returns to the sump (15) where it can be discharged to the sewer (16) **[B]** or undergo additional treatment which involves de-salination, reverse osmosis and ultra-filtration. After this treatment the effluent consists of de-salinated water and brine concentrate. The de-salinated water is pumped back to the tannery to be used in the production process. The brine concentrate (salt) is discharged to a high rate oxidation pond (20) for algae culture. A firm can reuse the salt that is left in the tannery. At this stage all that is left is a very low strength effluent to be discharged **[C]** (Rowswell, 1994).

4.3 The benefits and costs of treatment.

A firm using the treatment process outlined above could terminate the process at point A, B or C and in doing so incur neither the costs nor reap the benefits of further treatment. For any firm the principle will be the same i.e. in order to obtain the benefits of treatment (or increased treatment), firms have to incur costs. Therefore how much treatment they do depends on these relative costs and benefits, which are discussed below.

4.3.1 The benefits of treatment

The magnitude of these benefits depends on the amount of treatment done and, depending on the treatment process, could include one or more of the following:

a) reduced effluent disposal bill,

b) recycled materials,

c) recycled water, and

d) secondary products.

These benefits are discussed in greater detail below.

a) Reduced effluent disposal bill

As was shown in chapter three, if economic incentives are used then firms have to bear the cost of the effluent discharged, according to its strength and volume. If firms treat and in doing so, bring down either, or both, the strength or volume, they will reduce the amount they have to pay. The other component of the effluent disposal bill is the cost of solid waste disposal. Again a firm can reduce the size of this bill through treatment.

b) Recycling

Recycling has a number of benefits both environmental and economic. "It prevents wastes from reaching the environment and returns them to the production process and thus prevents pollution" (Pearce and Nash, 1979:184). Another benefit is that by recycling, virgin resources and the energy inputs required for their conversion into final products are saved. Economically, if the savings to be made from recycling are greater than the costs then it is beneficial for a firm to recycle. Furthermore the disposal costs of pollutants will decrease.

There are a number of potential problems involved in recycling. Very often it does not pay because the goods to be recycled are dispersed over a large geographical area and it is neither easy nor cheap to collect them again. Added to this, they have "usually undergone transformation during the production process that makes them difficult to integrate back into the production stream." There is also the danger of merely shifting pollution from one medium to another (DEA, 1993:21).

In the leather industry however, the problem of the emissions to be recycled being dispersed over a large area does not apply because they are already at the factory and so the collection costs are at worst marginal. Added to this the materials that can be recycled can easily be reintegrated back into the production stream and can be used as substitutes for virgin materials (Rowswell,1994). The treatment and recycling process will not shift pollution from one medium to another but instead will serve to decrease the amount of pollution discharged by a firm (Rowswell, 1994).

For a leather firm there is the potential to recycle some of the chemical inputs and water used in the production process and normally discharged in the effluent. The presence of chemicals in the effluent indicates a loss of process chemicals which also contribute to the overall treatment and disposal problems of the firm (WRC, 1987:8).

Chemicals that can be recycled are chrome, sulphur, lime and sodium chloride. Estimates, based on international experience, of the percentage of these chemicals that can be recycled, range from 30-35% of the chrome; 45-50% of the lime; 60-65% of the sulphur; and 100% of the sodium chloride used as inputs in the production process (Rowswell, 1994).

The benefits to the firm of recycling chemicals will be the revenue from their sale or re-use and a reduction in the effluent disposal bill because of a reduction in the strength and volume.

c) Recycling water.

Four ways in which some of the water present in the effluent can be recycled are by:

i) taking the water that has been used in a process requiring a relatively high quality of water and which results in a "relatively high quality of once used water", and using it in another "process or series of processes requiring a lesser quality of water".

ii) Doing a "minimum treatment of effluent from a particular process operation and re-use it in the same or in another compatible process."

iii) "Closed-loop collection and recycling of effluent from a particular process for re-use, with make-up of water and chemicals as required.

iv) End-of-line treatment of mixed factory effluent for re-use in selected factory applications" (WRC, 1987:8).

The benefits to the firm of recycling water are twofold. Firstly, there will be a decrease in their water bill because not as much clean water will be needed for the firms' production process. Secondly, there will be a reduction in the effluent disposal bill because of a decrease in the volume and strength of the effluent that will be discharged after recycling.

The magnitude of the benefit to be gained from recycling materials and water is going to depend on the type and amount of recycling done, the price of recycled materials and the cost of effluent disposal.

d) Secondary products.

It is possible for a firm, as a by-product of its treatment process, to produce secondary products. Examples include the use of treated sludge as a fertiliser and the use of treated effluent to grow algae that can be sold as fish food (Rowswell, 1994). The benefits to the firm will be the revenue gained from the sale of these secondary products and a reduction in the effluent disposal bill because of a decrease in the volume and strength of the effluent that still has to be disposed.

In order to gain the above mentioned benefits, a firm will incur the cost of treatment. These costs are examined in the next section.

4.3.2 The costs of treatment

The severity of the costs that a firm will incur because of treatment depends upon the amount and type done and will include the following:

a) capital costs of the treatment plant, and

b) input costs of the treatment plant.

These costs are discussed in more detail below.

a) Capital costs of the treatment plant.

Capital cost will vary, depending on the size of the treatment plant, the type of treatment process and the degree of treatment undertaken.

The size of the treatment plant depends on the amount of effluent that a firm wants to treat. Generally, the more skins and/or hides a firm processes, the greater the volume of effluent generated and therefore the larger the treatment plant needs to be. Obviously the larger the treatment plant the greater the capital cost.

The type of treatment process that the firm uses will affect the capital costs because different processes require different types of plant and equipment. For example, a chemical treatment process is cheaper than a biological plant in terms of capital costs, but more expensive to run (Rowswell, 1994).

Finally, the degree of treatment done will also affect the capital costs of the plant. For example, if a firm decides to treat and recycle its effluent then it is going to need a different type of plant and equipment to a firm which only wants to treat. Generally the greater the amount of treatment done, the greater the capital costs of the plant.

b). Input costs

While all firms that treat will incur some or all of the following input costs, their magnitude is going to vary depending on the type and amount of treatment done. These costs are:

a) labour costs,

b) electricity costs,

c) chemical costs,

d) maintenance costs (WRC, 1987:119).

It is not enough for firms to know what the costs and benefits of treatment are, they must be able to put a value to them. How this can be done is discussed in the next section.

4.4 Valuation of benefits and costs

4.4.1 Benefits

The value of the decrease in the effluent disposal bill will be equal to the cost of the charge plus the cost of solid waste disposal before treatment, minus the same two costs after treatment. The higher the costs the larger the value of the benefit.

The value of recycled chemicals will be equal to the quantity of the chemical recycled multiplied by the market price. The chemicals market price is taken because once recycled it can be used as a direct substitute for virgin chemicals (Rowswell, 1994).

The value of recycled water is equal to the amount by which clean water needed has decreased multiplied by its cost. The value of secondary products is the quantity of secondary products produced multiplied by their market price. The value of the decrease in the strength and volume of effluent due to recycling and the production of secondary products will be reflected in the effluent disposal bill discussed above.

4.4.2 Costs

The capital cost is equal to the cost of building the treatment plant plus the cost of the machinery and equipment used in the treatment process divided by the lifespan of the plant and equipment to give the yearly capital cost.

The value of the input costs can be derived as follows:
Labour costs: quantity of labour used x wage.
Chemical input costs: quantity of chemicals used x price of chemicals.
Electricity costs: quantity of electricity used x price of electricity plus the service charge.

4.5. The net benefits of treatment

Having outlined the relative costs and benefits of treatment, it is necessary to see whether it is economically viable for a leather firm to treat their effluent and if so, how much treatment to undertake. A formula has been developed to aid in this decision, namely:

$$NBT = [Pw + Prm_{(1...m)} + Psp_{(1...m)} + Ec^* + Cs^*] - [K + L_{(1...m)}]$$

Where:

Where:	NBT	=	Net Benefit of Treatment
	Pw	=	Value of recycled water
	$Prm_{(1...m)}$	=	Value of recycled materials
	$Psp_{(1...m)}$	=	Value of secondary products
	Ec*	=	net saving on municipal effluent charge
	Cs*	=	Net saving on solid waste disposal bill
	K	=	Capital cost of treatment plant
	$L_{(1...m)}$	=	Non-capital input costs of a treatment plant

If the net benefit of treatment is positive, then it is economically viable for a firm to treat its effluent. The amount of treatment undertaken should increase for as long as the net benefit of treatment is rising. It follows that if the net benefit of treatment is negative, it is not economically viable for the firms to treat and they would be better off disposing of their untreated effluent and paying the relevant costs. A firm will maximise its total benefits of treatment (TBT) if it undertakes treatment to the stage where its net benefits of treatment are equal to zero

An increase in the price or quantity of recycled water, chemicals or secondary products, an increase in the municipal effluent charge, or the cost of solid waste disposal, a decrease in the capital cost or the price or quantity of non-capital inputs would all increase the net benefit of treatment. The reverse would decrease the net benefit of treatment.

Having outlined the theoretical foundations of the economics of pollution control, we can move on to its application to the specific practical problem of controlling the effluent generated by leather firms. This is done by applying data relevant to the leather industry to the theory. A description, and the source, of that data is the subject of the next chapter.

CHAPTER 5 DATA DESCRIPTION AND SOURCES

Thus far the theoretical costs and benefits to be had by individual firms from effluent treatment as well as the theoretical gains that the use of economic incentives offer over a system of charges have been examined. However, given that the aim of this study is to see how the theory holds in practice, it is necessary to apply data, relevant to the leather industry, to the theory. Data is therefore required on what the actual treatment process of firms consists of, the capital and running costs of each stage of that process and the reduction in effluent strength after each stage of treatment.

The most difficult aspect of this study proved to be that of obtaining data on the leather firms' costs of treatment. While in theory it may seem like a relatively simple task of going to leather firms and extracting the costs from them, the reality of the situation was far different and a lot more complex than expected.

The reason for this was that although data was sought from a number of firms it was found that all only had a vague idea of what their total costs of treatment are. It was further found that they did not have a detailed account of their costs of treatment per stage, neither did they have a detailed account of the reduction in their effluent strength after each stage of treatment.

Two possible explanations for this could be that firstly, the firms investigated did honestly not have the above mentioned information; or secondly they did have it, but were not prepared to disclose it.

Whatever the reason, it necessitated finding alternative means of obtaining the data. This problem was overcome by using the treatment processes of two hypothetical firms cited in "A guide to waste-water management in the tanning and fellmongering industries" (WRC, 1987). The firms are a fellmongery and a chrome tannery. While the strength of the effluent and the performance efficiencies of the treatment plant are typical, it must be noted that we are only looking at 2 types of leather firms using a particular treatment process. There are both other types of firms and treatment processes. These 2 firms were chosen not only because they give a detailed outline of the treatment process but because the reduction in effluent strength after each stage of treatment is provided. Some alterations were made in consultation with LIRI.

Firm 1 is a fellmonger generating 500m^3 of raw effluent a day with the following strength:

Total COD 9000mg/l

Soluble COD 6000mg/l

Suspended solids 3000mg/l

Settleable solids 150ml/l

Sulphide 3000mg/l as NA_2S

The treatment process is illustrated in figure 5.1 and discussed below.

Treatment process 1

Raw effluent passes through a screen, to remove large solids, to a collection sump. From here it is pumped, at a controlled rate, to a primary settling tank where the solids settle. The sludge is pumped,via primary sludge pumps, to a holding tank. The rest of the effluent exits, by means of an overflow weir, and flows to a primary aeration tank. Following aeration, the effluent passes to an activated sludge reactor which consists of an aeration tank and a secondary settling tank. Some of the sludge from the settling tank is reintroduced to the aeration tank to supply it with micro-organisms. The sludge is pumped to the holding tank while the rest of the effluent is discharged to (the) sewer by way of an overflow weir. Sludge from the holding tank is released to drying beds for dewatering.

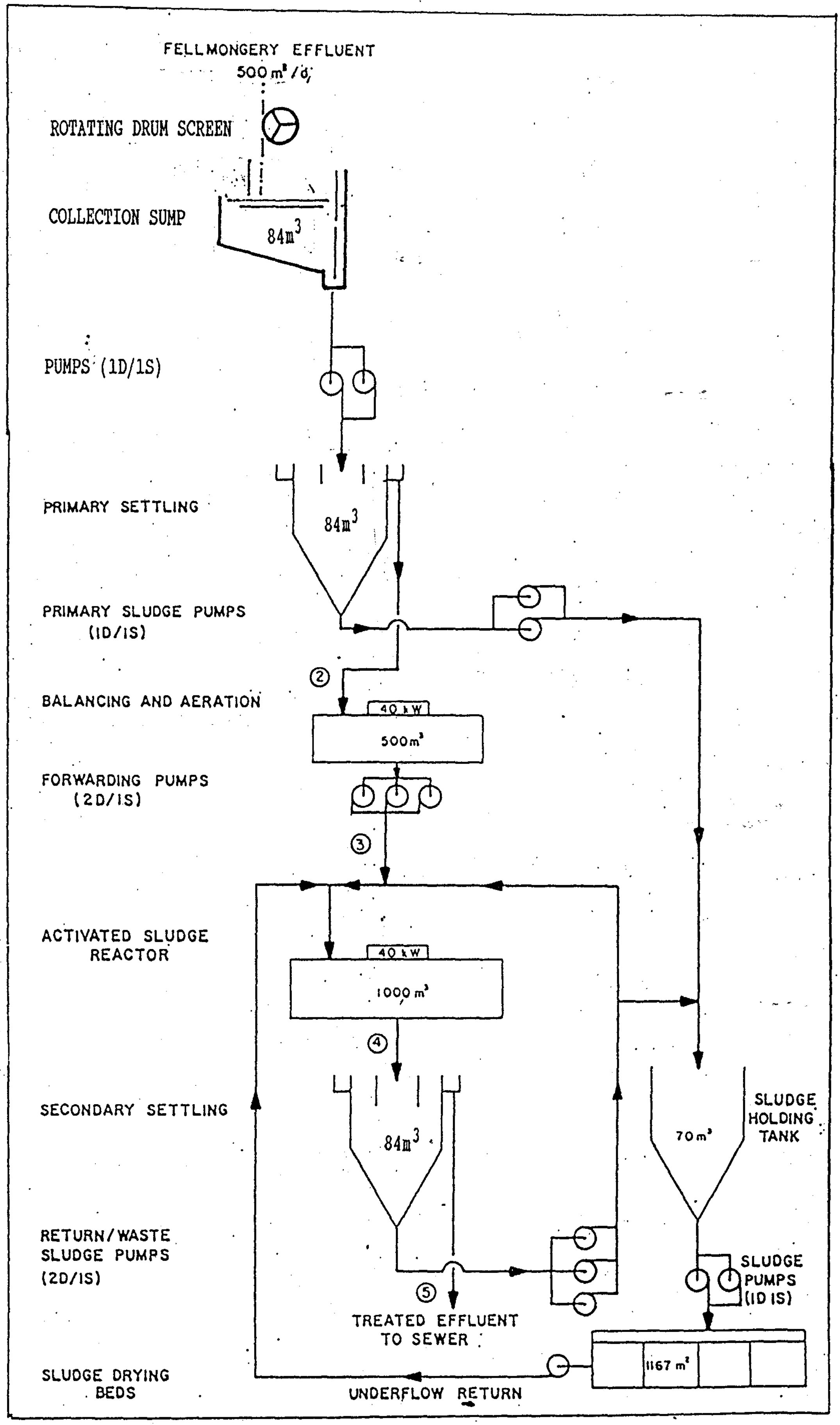

Figure 5.1: Treatment process 1

Source: Rowswell, 1994.

Firm 2 is a chrome tannery generating 800m^3 of raw effluent a day with the following strength:

Total COD 6000mg/l

Soluble COD 3500mg/l

Suspended solids 2000mg/l

Settleable solids 100ml/l

Sulphide 250mg/l as NA_2S

The treatment process is illustrated in figure 5.2 and is essentially the same as process 1 except that the quantity and quality of the effluent differs[4].

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[4] See appendix B for a more detailed and technical outline of both treatment process

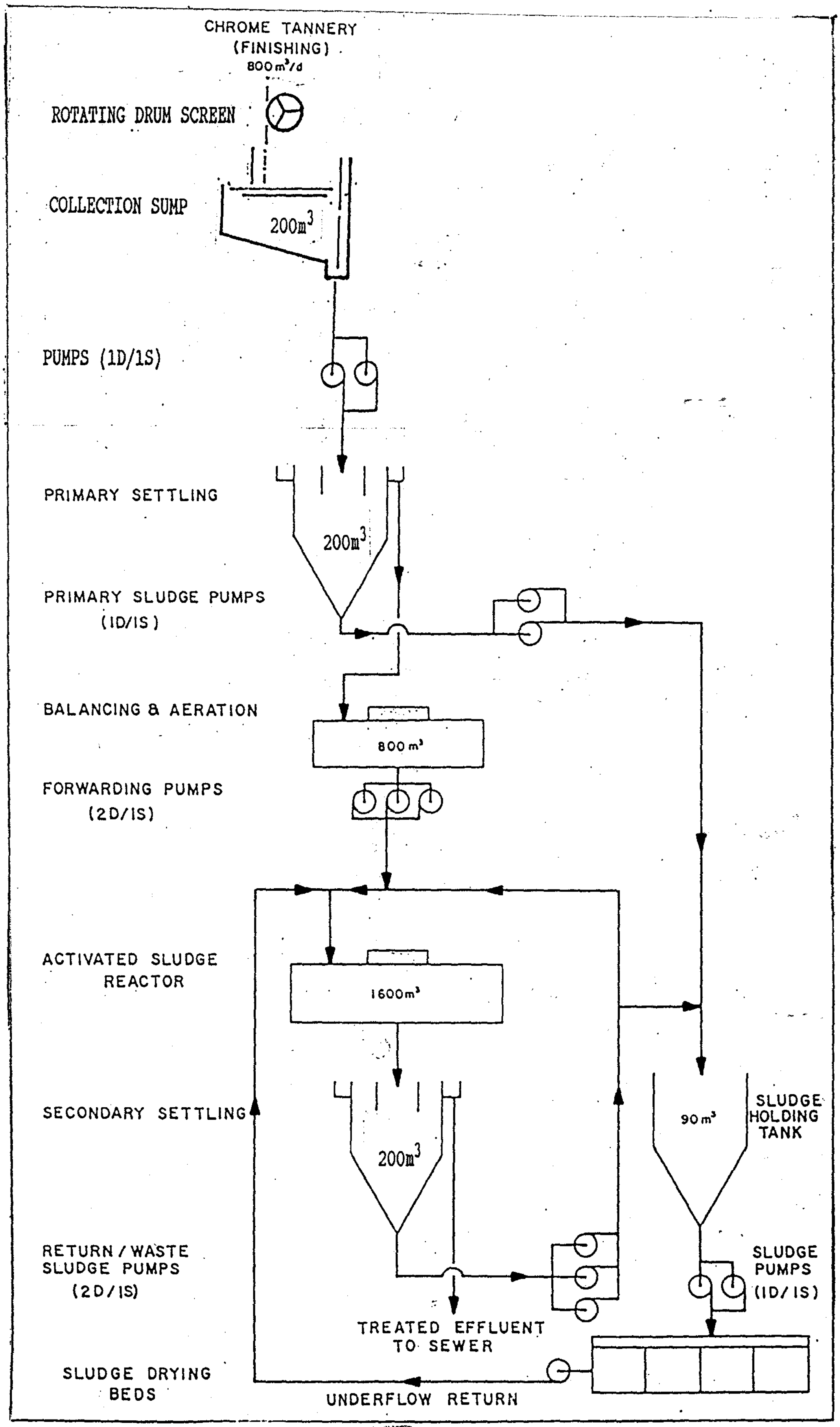

Figure 5.2: Treatment process 2

Source: Rowswell, 1994.

5.2. Costs[5]

To calculate the costs for the firms the following assumptions are made.

(i) As far as civil costs are concerned we assume that the ground that has to be excavated is the same for both firms. No allowance is made for rock excavation or unusual conditions. Furthermore all civil costs are inclusive of V.A.T. and consultants' fees and expenses.

(ii) Transportation costs of raw materials are zero for both firms.

(iii) Transportation costs of mechanical components are zero for both firms.

(iv) The strength of the effluent is measured by the chemical oxygen demand (COD).

(vi) Both firms discharge their effluent to the municipal sewer.

The total costs of treatment are made up of total fixed costs (TFC) i.e. the capital costs, and total variable costs (TVC) i.e. the running (or recurring costs).

Total fixed costs (TFC)

Total fixed costs will be costs that do not vary with treatment. They will be the same if effluent is reduced

[5] Costs are based on estimates and are net of plumbing costs.

by 1 or 10 000 units. The total fixed costs can be broken down into civil and mechanical costs. As was mentioned above leather firms were assumed not to have these costs. Therefore the treatment process outlined above was broken down into its various components. Quotations on the costs of the mechanical components were obtained from a commercial supplier of the plant items. The civil costs are based on estimates from a civil engineer (Cooper, 1995). All other costs are based on estimates from L.I.R.I. The lifespan of the civil components is taken as 25 years while those of the mechanical components is expected to be approximately 12 years. For convenience the latter costs were doubled as a rough approximation to make the lifespan of the entire plant 25 years. For a more accurate calculation appropriate discounting would have to be used.

The various components and their costs are as follows:

Table 5.1: TFC of treatment: firms 1 and 2

COMPONENT	COST(firm 1)	COST(firm 2)
Rotating drum and screen	R350 000$_1$	R250 000$_1$
Collection sump	R 68 000$_2$	R115 000$_2$
Stirrer	R 50 000$_1$	R 70 000$_1$
Pumps (1d/1s)	R 90 000$_1$	R180 000$_1$
Primary settling tank	R 53 600$_2$	R107 100$_2$
Primary sludge pumps (1d/1s)	R180 000$_1$	R260 000$_1$
Aeration tank	R175 000$_2$	R271 000$_2$
Aerator	R240 000$_1$	R340 000$_1$
Forwarding pumps (1d/1s)	R 70 000$_1$	R 70 000$_1$
Aeration tank	R336 000$_2$	R473 000$_2$
Aerator	R240 000$_1$	R340 000$_1$
Secondary settling tank	R 53 600$_2$	R107 100$_2$
Return/waste sludge pumps (2d/1s)	R200 000$_1$	R280 000$_1$
Sludge holding tank	R 49 800$_2$	R 58 300$_2$
Stirrer	R 50 000$_1$	R 70 000$_1$
Sludge pumps (1d/1s)	R 80 000$_1$	R100 000$_1$
Sludge drying beds	R 28 420$_3$	R 35 500$_3$
Total	R 2.314m	R 3.127m

Notes:1. Source: Dreglon, 1995
2. Source: Cooper, 1995
3. Source: Rowswell, 1995

Therefore the TFC of treatment process 1 will be R2.314 million. It is however necessary to break the TFC down into TFC per treatment period[6]. The figures have been adjusted so that a period is 24 hours.

The TFC per year are the TFC divided by the lifespan of the plant. Although this is a rather crude method, and there are more sophisticated methods available, it will have to suffice for our purposes. Therefore, based on information from the manufacturers and the civil engineer the lifespan of the plant will be 25 years. The TFC per year will therefore be R2.314 million/25 = R92 576.80 per year.

It is assumed that leather firms are operational 240 days a year. The TFC per treatment period will therefore be R92 576.80/240 = R385.74. per day.

The TFC per treatment period for firm 2 is worked out in the same way and is as follows:

TFC: R3.127m

Lifespan of the plant: 25 years.

TFC per year equals R3.127m/25 = R125 080.

Assuming that the plant is operational 240 days a year,

[6] A treatment period is defined as the time it takes for one day's effluent to pass through the treatment process.

the TFC per treatment period will be R125 080/240 = R521.16. per day.

(ii) Total variable costs

The total variable costs (TVC) are the costs that vary directly with the amount of treatment. In this case they consist of the running costs of the treatment plant, namely of the electricity usage of the various mechanical components of the treatment process. The amount of time that the components run for and power used is determined by the quantity and strength of the effluent and the degree of treatment that firms do (Dreglon, 1995). The cost of the electricity needed is based on data provided by the Port Elizabeth Municipality (Bruce, 1995). The running costs per treatment period will therefore be as follows:

Table 5.2: Total variable costs of treatment process 1

COMPONENT	Kw/h_1	hrs/day_1	Kw/day	$Cost_2$ (R)
Rotating screen and drum	2	11	22	2.49
Stirrer	2	11	22	2.49
Pump	3	10	30	3.40
Primary sludge pumps	3	6	18	2.04
Aerator (2x22Kw)	44	24	1056	119.54
Forwarding pumps	6	7	42	4.75
Aerator $(2x22Kw)_3$	88	24	2112	239.08
Return/waste sludge pumps	4	5	20	2.26
Sludge pumps	2	3	6	0.68
Stirrer	3	11	33	3.74
kVA_4				76.72
TOTAL				457.19

Notes:1. Source: Dreglon, 1995.
2. Source: Bruce, 1995. (cost per kw is R0.1132)
3. Aeration time is 48 hours therefore Kw/h has been doubled
4. kVA is a charge, levied by the municipality, based on a firm's peak demand for electricity. It is calculated by taking the peak demand for 1 hour's electricity and multiplying it by a factor of 0.8. This figure is then multiplied by a charge of R19.97 to give the kVA charge for the month.(Bruce,1995) Based on the assumption that leather firms are operational 20 days a month, the charge has been divided by 20 to give the daily kVA charge.

The total variable cost per treatment period will therefore be R457.19

Table 5.3: Total variable costs of treatment process 2

COMPONENT	Kw/h_1	hrs/day_1	Kw/day	$Cost_2$ (R)
Rotating screen and drum	3	11	33	3.74
Stirrer	3	11	33	3.74
Pump	6	10	60	6.79
Primary sludge pumps	5	6	30	3.40
Aerator (2x30Kw)	60	24	1440	163.01
Forwarding pumps	6	7	42	4.75
Aerator $(2x30Kw)_3$	120	24	2880	326.02
Return/waste sludge pumps	4	5	20	2.26
Sludge pumps	3	3	9	1.02
Stirrer	3	11	33	3.74
kVA				104.51
TOTAL				622.98

Notes:1. Source: Dreglon, 1995
2. Source: Bruce, 1995 (cost per kw is R0.1132)
3. Aeration time is 48 hours therefore Kw/h has been doubled

The total variable cost per treatment period will therefore be R622.98

5.3. Total cost per treatment period per stage.

The treatment process can be broken down into various stages of treatment, the details of which are contained in appendix C. These are:

Table 5.4: Treatment costs per stage: firm 1.

STAGE	PROCESS	TFC (R)	TVC (R)	TC (R)
	Pretreatment	93	10.84	103.84
1	Primary settling	164.67	18.76	183.43
2	Primary aeration	233.84	168.45	402.29
3	Activated sludge reactor	385.74	452.18	837.83

Table 5.5: Treatment costs per stage: firm 2

STAGE	PROCESS	TFC (R)	TVC (R)	TC (R)
	Pretreatment	102.50	18.46	120.96
1	Primary settling	204.67	28.38	233.05
2	Primary aeration	306.50	239.32	545.82
3	Activated sludge reactor	521.16	623.04	1 144.20

Marginal abatement costs

The marginal abatement costs (MAC) are additional total abatement costs per unit change in effluent strength.

The reduction in effluent strength after each stage of treatment will be as follows:

Table 5.6: Per stage reduction in effluent strength :treatment process 1

Stage	Effluent strength (kg of COD_1)	Change in effluent strength (kg)
Raw	4 500	
1	3 550	950
2	2 336	1 214
3	630	1 706

Notes 1. Source: WRC, 1987:89-94.

Table 5.7: Per stage reduction in effluent strength: treatment process 2

Stage	Effluent strength (kg of COD_1)	Change in effluent strength (kg)
Raw	4 800	
1	3 376	1 424
2	3 220	156
3	960	2 260

Notes. 1. Source: WRC, 1987: 95-99.

The MAC per stage per Kl (derived from the TAC per stage per Kl will be as follows:

Table 5.8: MAC: Treatment process 1

STAGE	Change in TAC (R)	Change in effluent strength	MAC (cents)
0	103.84	0	0
1	79.59	950	8.38
2	218.86	1 224	18.03
3	435.54	1 706	25.53

Table 5.9: MAC: Treatment process 2

STAGE	Change in TAC (R)	Change in effluent strength	MAC (cents)
0	120.96	0	0
1	112.09	1 424	7.87
2	312.77	156	200.49
3	598.38	2 260	26.48

Having broken the cost of treatment and the effluent reduction into stages, it is possible to derive the total abatement cost (TAC) curves for firms 1 and 2. This is done by plotting the strength of the effluent, on the X axis, against the cost of reducing that strength, on the

Y axis. It is interesting to note that the effluent strength was reduced in "lumps" rather than in a smooth progression. The reason for this is because all of the effluent is treated, at each stage, for the full duration of the process. This is reflected in the "stepped" nature of the TAC curves which are illustrated below.

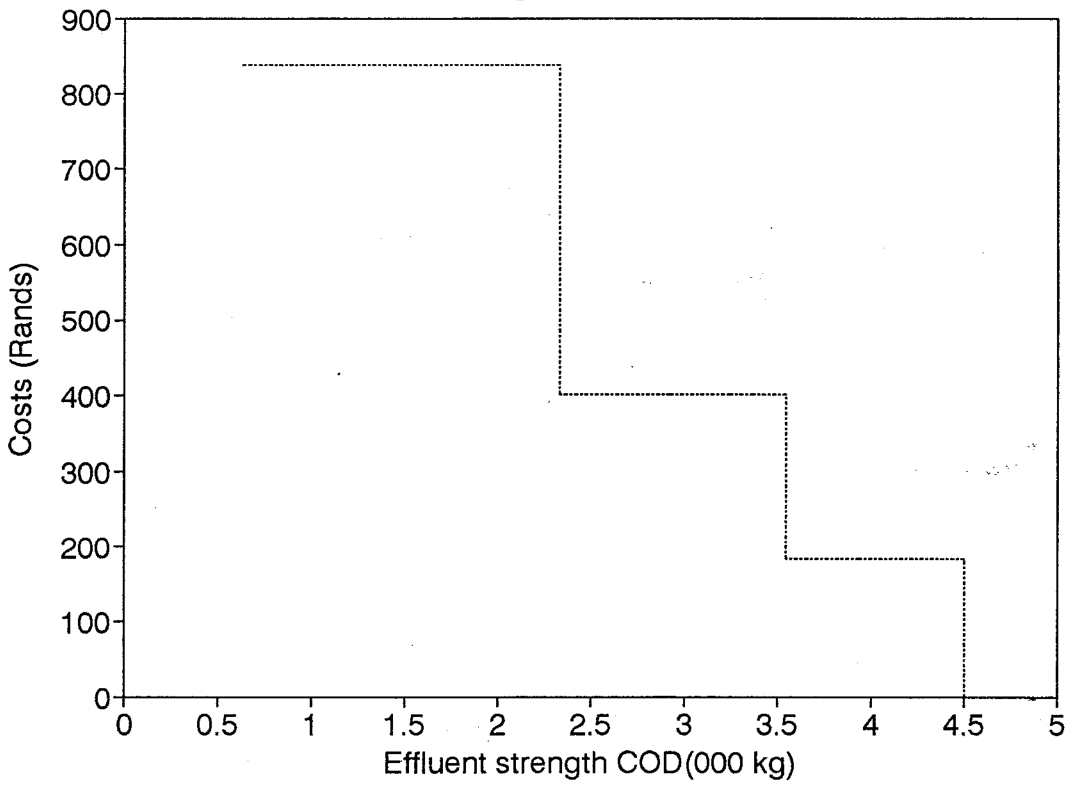

Figure 5.3: Total abatement costs of firm 1.

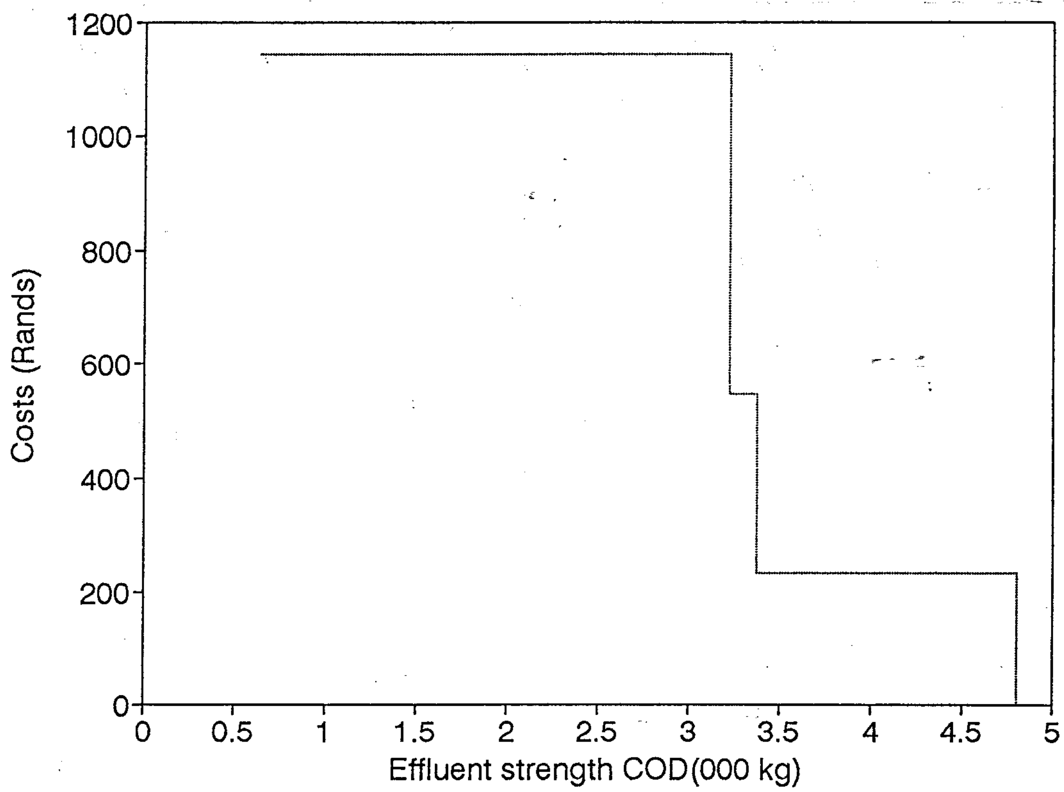

Figure 5.4: Total abatement costs of firm 2.

Having worked out the marginal abatement costs per stage of treatment and knowing the change in effluent strength after each stage of treatment, it is possible to derive the marginal abatement cost (MAC) curves for firms 1 and 2. The strength of the effluent is once again shown on the X axis. The Y axis shows the MAC, or extra cost of reducing the effluent by expenditure on treatment. Given that the MAC curves are derived from the TAC curves they will also be "stepped" and are illustrated in figures 5.5 and 5.6.

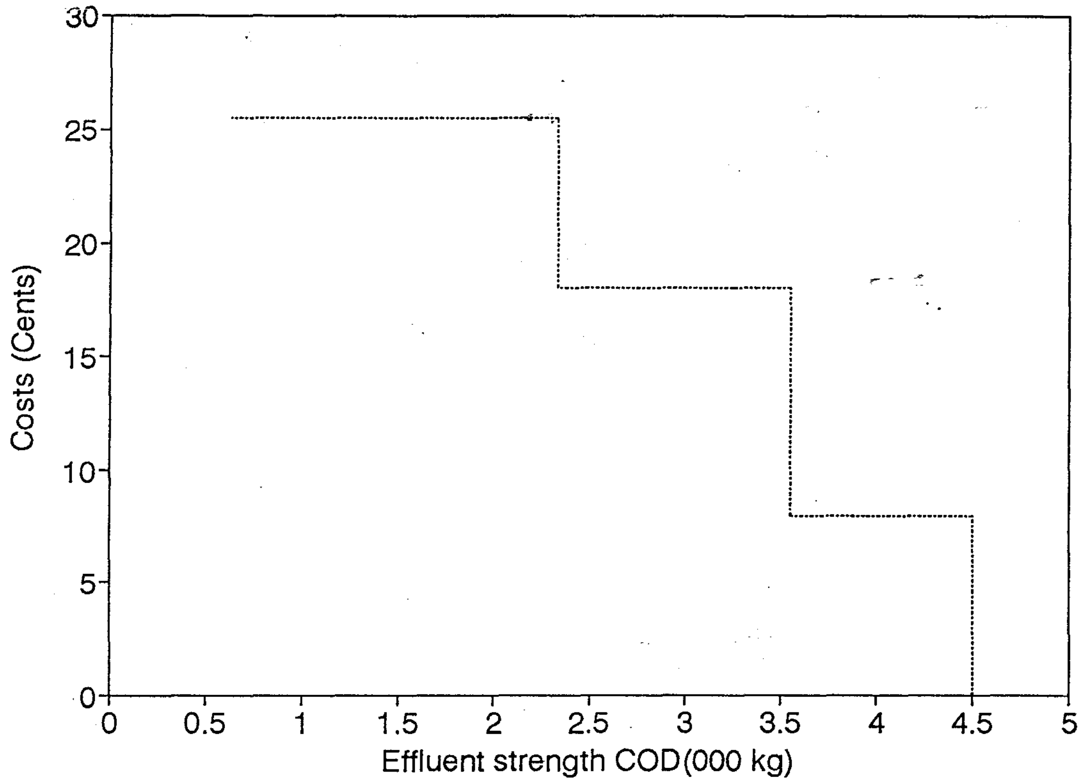

Figure 5.5: Marginal abatement costs of firm 1.

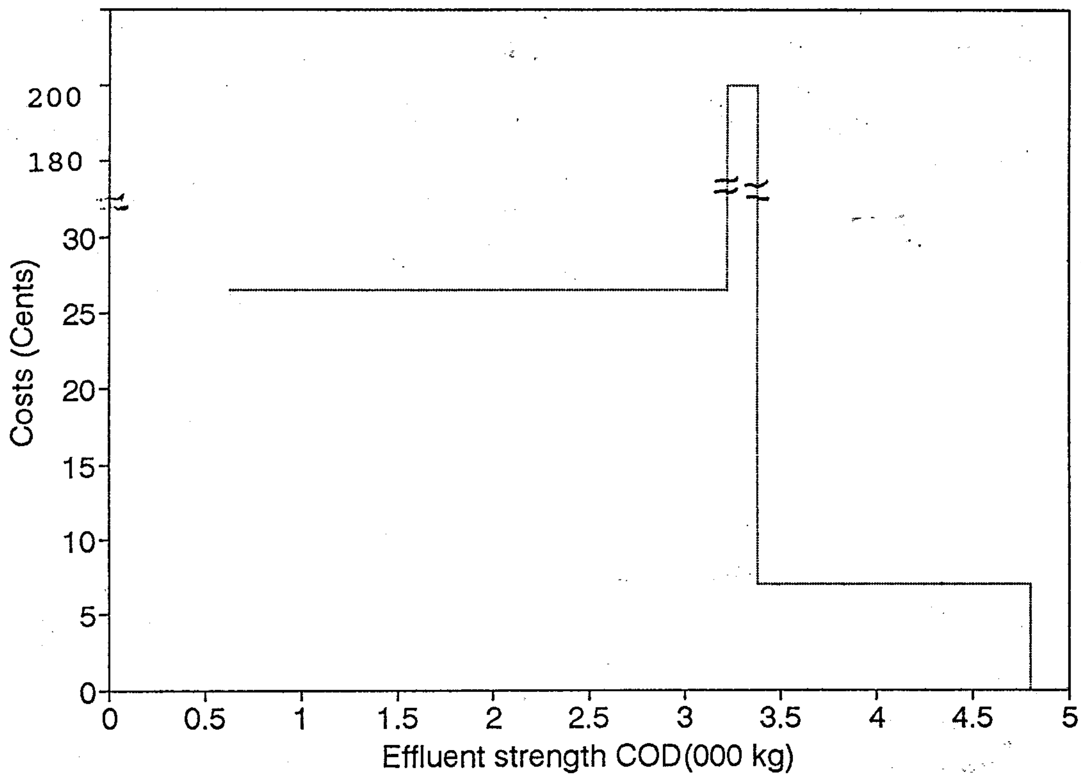

Figure 5.6: Marginal abatement costs of firm 2.

In the following chapter, the data outlined above are applied to the theory discussed earlier.

APPENDIX B

Treatment process 1

Design

Raw effluent flows via a rotating drum and passes through a screen which retains the larger solids and allows the liquid to pass through to a collection sump.

The collection sump is concrete and able to hold 2 hours of effluent. Assuming the peak flow rate into the primary settling tank is required to be twice the average daily flow, the design flow is 2x500/24= 41.7m^3/h. The collection sump should therefore be 2x41.7m^3= +/- 84m^3. The collection sump is fitted with a stirrer to maintain solids in suspension.

Flow rate to the primary settling tank is 41.7m^3/h and is regulated by means of a pump.

The settling tank should be able to hold 2 hours flow (i.e. 84m^3). The solids settle down to the bottom of the settling tank and exit by means of a valve, via primary sludge pumps, to a sludge holding tank. The rest of the effluent is discharged from the primary settling tank, by means of a peripheral overflow weir, to an aeration tank.

The aeration tank is concrete and able to hold 500m^3. Oxygen is supplied by 2 vertical shaft fixed bridge slow speed aerators with a power rating of 22Kw each. Effluent exits, by means of an overflow weir, to an Activated sludge reactor.

The activated sludge reactor has a 2 day retention period and consists of an aeration tank and a secondary settling tank. Some of the sludge from the secondary settling tank is reintroduced into the aeration tank to supply it with micro-organisms.

The aeration tank is concrete and able to hold 1000m^3. Aeration requirement is supplied by 2 vertical shaft fixed bridge slow speed aerators with a power rating of 22Kw each. Effluent exits, by means of an overflow weir, to the secondary settling tank.

The secondary settling tank is the same as the primary settling tank but now some of the sludge is pumped back to the aeration tank by means of pumps. Liquid effluent is discharged to sewer by means of an overflow weir. The settled solids are discharged to the sludge holding tanks.

The sludge holding tank must be able to hold 70m^3. It is equipped with a stirrer to maintain solids in suspension. Sludge is released, to sludge drying beds for dewatering, by means of a valve at the bottom of the tank.

Treatment process 2

This process is essentially the same as process 1, except that the quantity and quality of the effluent is different. The differences this causes in the treatment process is in the size of the various components. These are now:

1) Rotating drum and screen.
2) Collection sump:Concrete tank vol. $200m^3$ (flow rate $100m^3/h$)
   fitted with a stirrer
   pump
3) Primary settling tank with peripheral overflow weir.
   concrete, vol. $200m^3$
4) Aeration tank: concrete, vol. $800m^3$
   aerators: 2x30Kw
5) Activated sludge reactor
   (a) Aeration tank vol. $1600m^3$
   aerators: 2x30Kw
   (b) Secondary settling tank with peripheral overflow weir.
   concrete, vol. $200m^3$
6) Sludge holding tank
   Vol. $90m^3$
   stirrer
7) Sludge drying beds.

APPENDIX C

Total costs of treatment per stage and per treatment period are as follows. Treatment process 1:

Table 5.10: TFC: pre treatment stage

COMPONENT	COST (R)
Rotating drum and screen	350 000
Collection sump ($84m^3$)	68 000
Stirrer	50 000
Pump	90 000

TFC = R558 000
TFC = R558 000/25/240 = R93 per treatment period

Table 5.11: TVC: pretreatment stage

COMPONENT	COST (R)
Rotating drum and screen	2.49
Stirrer	2.49
Pump	3.40
kVA	2.46

TVC = R10.84
TC = TFC + TVC = R103.84 per treatment period

Table 5.12: TFC: stage 1

COMPONENT	COST (R)
Primary settling tank ($84m_3$)	53 600
Primary sludge pumps	180 000
Sludge holding tank ($70m^3$)	49 800
Stirrer	50 000
Sludge pumps	80 000
Sludge drying beds ($70m^2$)	17 150

TFC = R430 550
TFC = R430 550/25/240 = R71.76 per treatment period

Table 5.13: TVC: stage 1

COMPONENT	COST (R)
Primary sludge pumps	2.04
Sludge pumps	0.34
Stirrer	3.74
kVA	1.80

TVC = R7.92
TC = TFC + TVC = R79.59 per treatment period.

Table 5.14: TFC: stage 2

COMPONENT	COST (R)
Aeration tank (500m$_3$)	175 000
Aerator (2x22Kw)	240 000

TFC = R415 000
TFC = R415 000/25/240 = R69.17 per treatment period.

Table 5.15: TVC: stage 2

COMPONENT	COST (R)
Aerator	119.54
kVA	30.15

TVC = R149.69
TC = TFC + TVC = R218 86 per treatment period.

Table 5.16: TFC: stage 3

COMPONENT	COST (R)
Forwarding pumps	70 000
Aeration tank (1000m$_3$)	336 000
Aerator (2x22Kw)	240 000
Secondary settling tank (84m$_3$)	53 600
Return waste sludge pumps	200 000
Sludge drying beds 46m^3	11 270

TFC = R910 870
TFC = R910 870/25/240 = R151.81 per treatment period.

Table 5.17: TVC: stage 3

COMPONENT	COST (R)
Forwarding pumps	4.75
Aerator	239.08
Sludge pumps	0.34
Return sludge pumps	2.26
kVA	37.30

TVC = R283 73
TC = TFC + TVC = R435.54 per treatment period.

Total costs of treatment per stage and per treatment period. Treatment process 2

Table 5.18: TFC: pre treatment stage

COMPONENT	COST (R)
Rotating drum and screen	250 000
Collection sump (200m^3)	115 000
Stirrer	70 000
Pump	180 000

TFC = R615 000
TFC = R615 000/25/240 = R102.50 per treatment period.

Table 5.19: TVC: pretreatment stage

COMPONENT	COST (R)
Rotating drum and screen	3.74
Stirrer	3.74
Pump	6.79
kVA	

TVC = R18.46
TC = TFC + TVC = R120.96 per treatment period.

Table 5.20: TFC: stage 1

COMPONENT	COST (R)
Primary settling tank (200m$_3$)	107 100
Primary sludge pumps	260 000
Sludge holding tank (90m^3)	58 300
Stirrer	70 000
Sludge pumps	50 000
Sludge drying beds (72m^2)	17 640

TFC = R613 040
TFC = R613 040/25/240 = R102.17 per treatment period.

Table 5.21: TVC: stage 1

COMPONENT	COST (R)
Primary sludge pumps	3.40
Sludge pumps	0.45
Stirrer	3.74
kVA	2.33

TVC = R9.92
TC = TFC + TVC = R112.09 per treatment period.

Table 5.22: TFC: stage 2

COMPONENT	COST (R)
Aeration tank (800m_3)	271 000
Aerator (2x30Kw)	240 000

TFC = R611 000
TFC = R611 000/25/240 = R101.83 per treatment period.

Table 5.23: TVC: stage 2

COMPONENT	COST (R)
Aerator	163.01
kVA	47.93

TVC = R210.94
TC = TFC + TVC = R312.77 per treatment period.

Table 5.24: TFC: stage 3

COMPONENT	COST (R)
Forwarding pumps	70 000
Aeration tank (1600m_3)	473 000
Aerator (2x30Kw)	340 000
Secondary settling tank (200m_3)	107 100
Sludge drying beds 73m^3	17 885

TFC = R1 287 985
TFC = R1 287 985/25/240 = R214.66 per treatment period.

Table 5.25: TVC: stage 3

COMPONENT	COST (R)
Forwarding pumps	4.75
Aerator	326.02
Return sludge pumps	2.26
Sludge pumps	0.54
kVA	50.15

TVC = R383.73
TC = TFC + TVC = R598.38 per treatment period.

CHAPTER 6 A PRACTICAL APPLICATION OF ENVIRONMENTAL ECONOMIC THEORY TO THE CONTROL OF EFFLUENT DISCHARGE BY LEATHER FIRMS

In this chapter the data outlined in Chapter 5 is applied to the environmental economic theory examined in Chapter 3 and the theoretical costs and benefits of a firm's treatment investigated in Chapter 4, in order to ascertain whether the theory holds in practice. Before this is done there are a number of assumptions that need to be made, namely:

(i) that two firms make up the leather industry;
(ii) the strength of the effluent is measured by its chemical oxygen demand (COD). There are therefore no parameters. By this it is meant that although there may be other pollutants present in the effluent, they are not taken into account;
(iii) the predetermined maximum level of effluent that can be discharged each day is 5 850 kilograms of COD; and
(iv) if the cost of treatment is the same as a charge or the price of a permit, firms will prefer to treat. (The need for this assumption is to avoid the problem of an indeterminate equilibrium which arises from the "stepped" nature of the MAC curves).

6.1 Standards

According to the theory outlined in chapter 3, where a standard for compliance is initiated the regulating authority inform the firms of the appropriate reduction in pollution required to meet the standard. If all firms, regardless of their individual costs of control, are required to limit pollution by the same amount, the pollution reduction will not be done at a minimum cost to society. This can be illustrated with the aid of figure 6.1 and table 6.1.

Table 6.1: Total abatement costs and effluent strengths of firms 1 and 2.

Stage	Firm 1 (TAC) (R)	Firm 2 (TAC) (R)	Effluent strength 1 (kg)	Effluent strength 2 (kg)
0	103.84	120.96	4 500	4 800
1	183.43	233.05	3 550	3 376
2	402.29	545.82	2 336	3 220
3	837.83	1 144.20	630	960

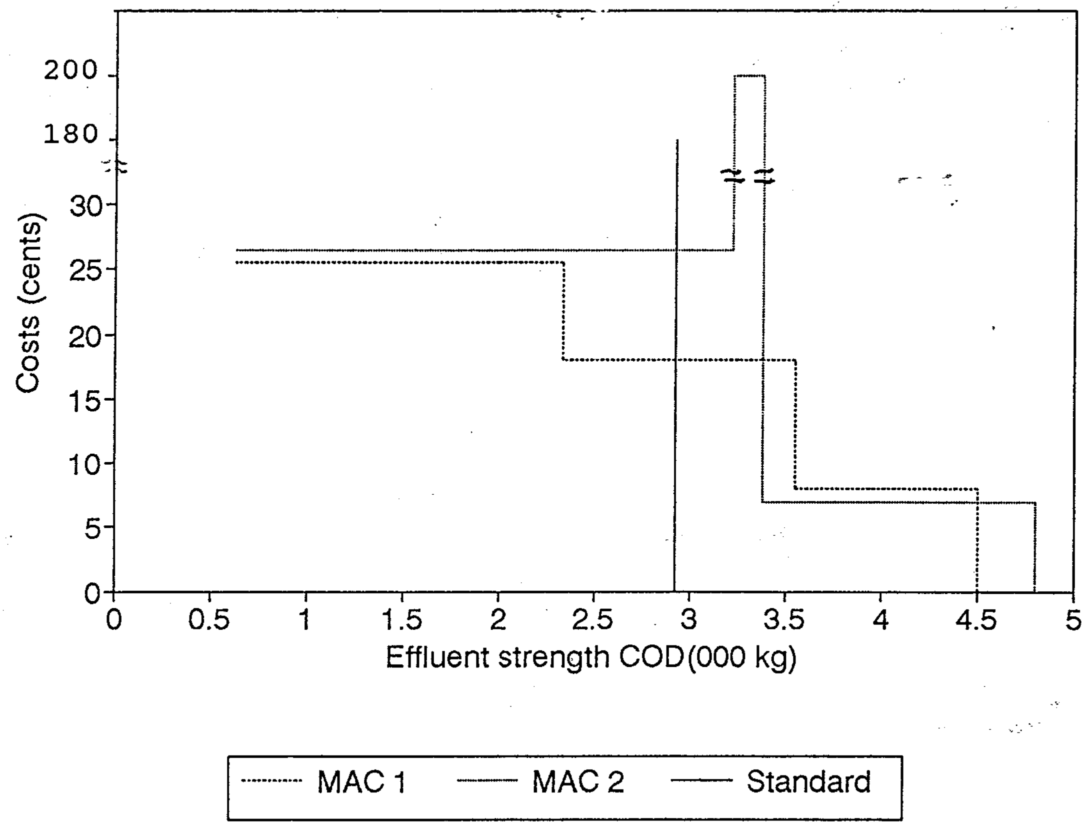

Figure 6.1: The use of standards to achieve a predetermined level of effluent discharge.

Assume, in figure 6.1, that the regulator says that the overall strength of the effluent must be reduced to 5 850 kg of COD and therefore tells each firm to cut their effluent strength to 2 925kg. The cost to the economy as a whole would be the cost to firm 1 plus the cost to firm 2 of cutting their respective effluent strengths to the stipulated level.

Therefore from figure 6.1 it can be seen that firm 1 would have to undertake stage 1 and 2 of its treatment process, in order to fall within the stipulated level. Firm 2 would need to do all three stages of treatment. From table 6.1, the overall cost of using standards to achieve the predetermined level of effluent strength would be R1 546.49; R402.29 for firm 1 and R1 144.20 for firm 2.

This method, while a solution to the pollution abatement problem, constitutes a very expensive means of achieving the desired result. The reason for this is that a system of standards has not taken into account the underlying differences in the firms treatment costs.

6.2 Charges

In Chapter 3 it was shown that standard setting incurs greater total abatement costs than taxing to achieve the same standard. Therefore the use of taxes is seen as a low cost solution to the abatement problem when compared to standards. This can be shown to hold in practice and is illustrated in figure 6.2.

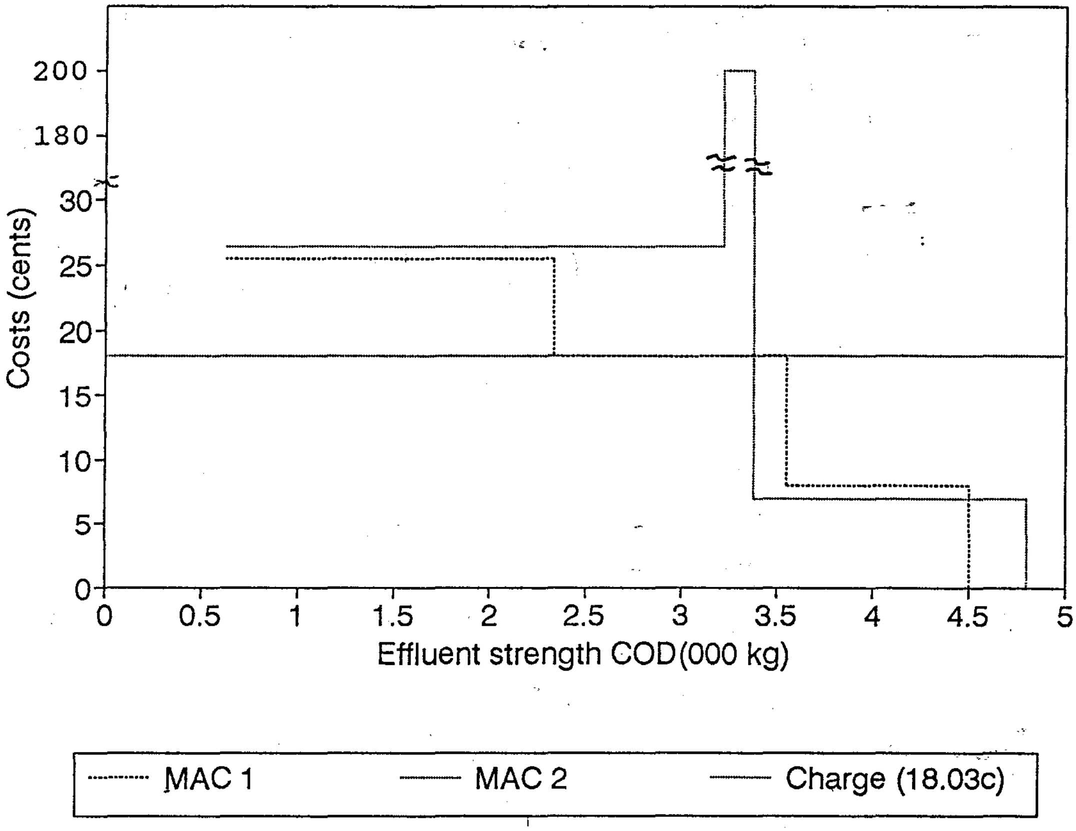

Figure 6.2: The use of a charge to achieve a predetermined level of effluent discharge.

Assume that the regulating authority wants to obtain the same overall optimal level of effluent as under a system of standards. Further assume that the authority, having perfect knowledge of the relevant cost functions, sets a charge of 18.03c per kilogram of COD discharged. Firm 1, given its costs of treatment, will respond by undertaking stages 1 and 2 and thereby reducing the strength of its effluent by 2 164kg to 2 336kg. Firm 2 would only undertake stage 1 and reduce the strength of its effluent by 1 424kg to 3 376kg. The overall strength of the effluent is therefore (2 336 + 3 376) 5 712kg which is within the desired level of effluent strength.

From table 6.1, the cost of achieving the overall standard under a system of charges has been Firm 1's treatment cost of R402.29 plus Firm 2's cost of R233.05. Therefore the total cost is R635.34 compared to the cost of R1 546.49 under a system of standards. Hence it can be seen that in practice, a system of charges is a lower cost method of achieving the predetermined effluent strength than standards. Although the firm's costs are estimates and are net of plumbing costs, an idea of the magnitude of the savings to be had under a system of charges is evident. The saving will obviously be the cost of achieving the predetermined level under a system of standards (R1 546.49) minus the costs of achieving the same level under a system of charges (R635.34) and is R911.15. This will be per day. Based on the assumption in chapter 5 that leather firms are operational 240 days a year, the saving per year would be approximately R218 000. If this were to be extended to a large number of firms in a number of industries, the magnitude of the saving would be even more substantial.

6.3. Subsidies.

The theory maintains that the payment of a per unit subsidy by the environmental authority to the polluter for abatement leads to the same outcome as the imposition of a charge. This can be illustrated with the aid of figure 6.3.

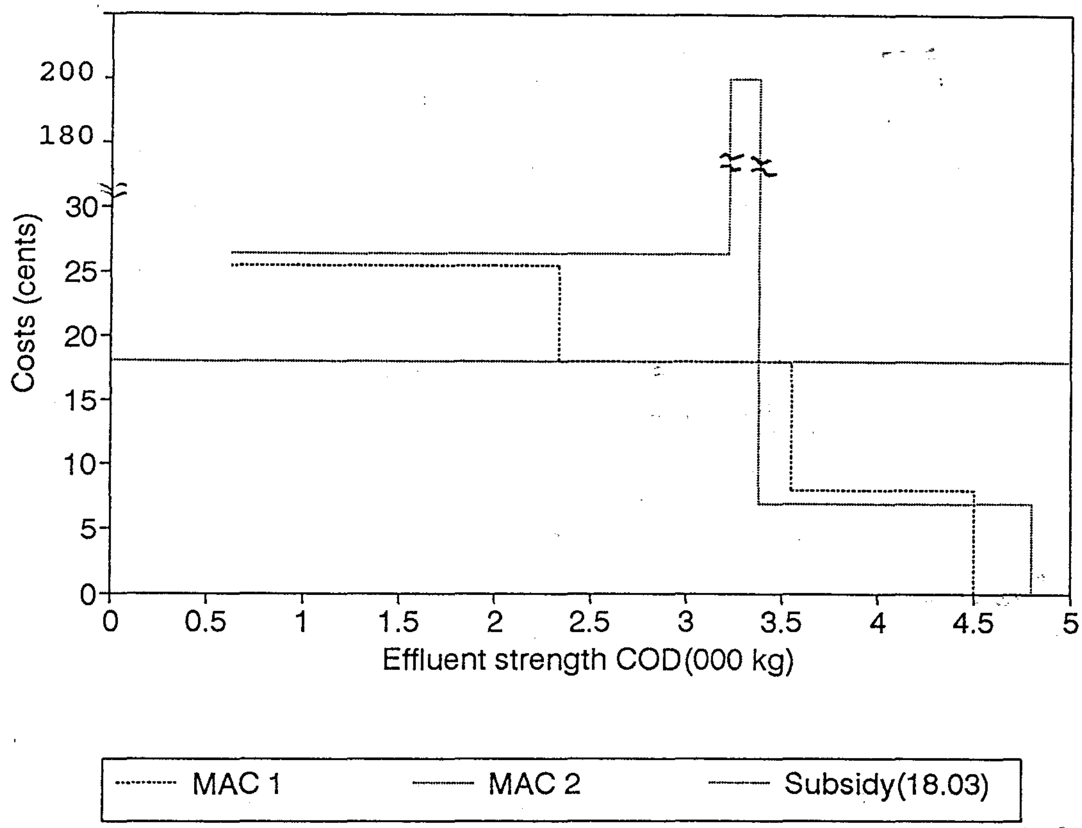

Figure 6.3: The use of a subsidy to achieve a predetermined level of effluent discharge.

Assume, in figure 6.3, that the environmental authority offered a subsidy of 18.03c per kilogram of COD not discharged. Firm 1 would undertake stage 1 and 2 of its treatment process while Firm 2 would do only stage 1, because it is profitable to do so. Thus we can see that the reduction in effluent strength will be the same as it is under a charge. Furthermore the total cost of abatement will be R635.34 which is the same as that under a charge. However, the disadvantages of a subsidy, discussed in chapter 3, would still hold (See 3.3.2).

6.4. Marketable permits

The theory outlined in chapter 3 maintains that the use of marketable permits will lead to the same least cost solution to controlling pollution as charges. However marketable permits have the added advantage of reducing the uncertainty and adjustment costs, involved in attaining the required levels of environmental quality, that was found to exist in charges and subsidies. They also take into account economic growth and inflation.

Before the data is applied to the theory of marketable permits, a number of assumptions need to be made, namely:

(i) one permit allows the holder to discharge one kilogram of COD per day;
(ii) the cost of the permits is equal to the number of permits multiplied by their price;
(iii) as long as the cost of treatment and the price of permits are the same, firms will prefer to treat; and
(iv) firms may only discharge effluent if they have a permit to do so.

As mentioned above, permits, like charges, offer the same cost minimising solution to pollution abatement. The regulating authority can directly restrict the strength of the effluent by restricting the number of permits that it issues. Assume once again that the two firms make up the industry. Furthermore assume that the regulating authority wants to reduce the strength of the effluent to the same optimal level of 5 850kg of COD. They therefore issue 5 850 permits. The price of the permits will be determined in the market by the interaction of the demand

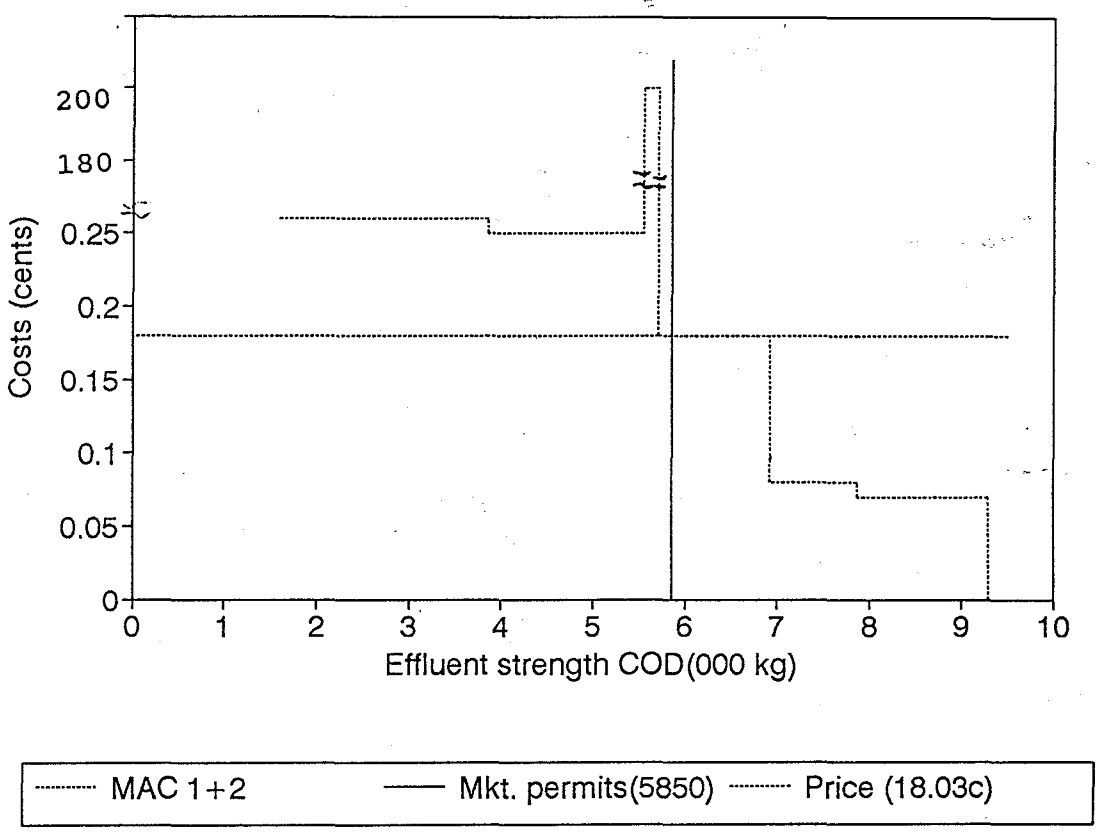

Figure 6.4: Market demand,supply and price of permits.

Given that the sum of the MAC curves is the industry demand curve for permits and that the authorities supply

5 850 permits, the price per permit would be 18.03c (this is based on and dependent on the firms MAC).

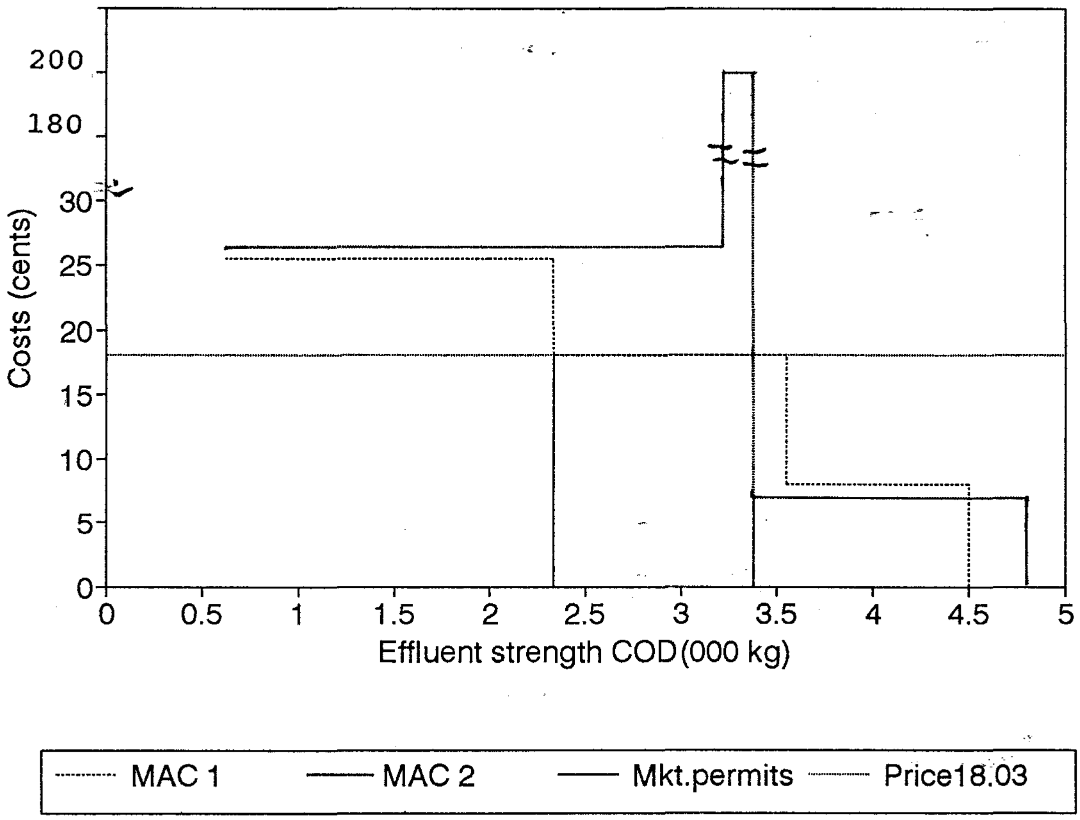

Figure 6.5: The use of marketable permits to achieve a predetermined level of effluent discharge.

From figure 6.5 it can be seen that at this price firm 1 will demand 2 336 permits and thereby be able to discharge 2 336kg of COD. Firm 2 would demand 3 376 permits and so discharge 3 376kg of COD. The total strength of the effluent discharged by the firms will therefore be 5 712kg of COD.

As can be seen from figure 6.5, polluters with high abatement costs (firm 2) will prefer to buy permits while low abatement cost firms (firm 1) will prefer to sell permits in favour of abatement. Furthermore the cost of abating pollution has been done at a lower cost to society than under a system of standards. In fact the outcome is exactly the same as it was under a system of charges and subsidies i.e R635.34.

While it can be seen that the actual cost of reducing pollution to a predetermined level is the same for charges, subsidies and marketable permit, it could be argued that the latter are the most economically efficient. The reason for this is because they do not include the costs involved in trying to set a charge or subsidy on a trial and error basis. Furthermore, marketable permits also take into account economic growth and inflation, would automatically adjust to new entrants and allow standards to be varied with comparative ease.

6.5. Charge 2

According to the theory discussed in chapter 3 and applied above, a charge is set, or marketable permits supplied, so as to get firms to reduce their effluent to a predetermined level. Furthermore this will be achieved at a lower cost than under a system of standards. In practice a system of charges is used to control the pollution that is generated by the leather industry. The charge however differs significantly from the one envisaged by the theory and discussed above. It is not set so as to get firms to reduce their effluent to a predetermined level. Rather, it is set based on the municipality's cost of treatment, at a level that will allow the firms, in conjunction with the municipality, to reduce the effluent to a predetermined level[7]. The significance of the charge being based on the municipality's cost is that it does some of the treatment involved.

As with the other economic incentives that we have looked at, firms still bear the cost of reducing the effluent to the predetermined level. Furthermore they should treat until their MAC are equal to the charge. The difference is that where the municipality can treat at a lower cost than the firms, the cost of achieving the predetermined standard will be at least cost compared to the low cost solution of the other incentives discussed thus far.

A charge set in the above manner is called charge 2 simply to differentiate it from the charge set in accordance with the theory, which from now on will be referred to as charge 1. Furthermore the institution doing the treatment will be referred to as a central treatment agency (C.T.A.) because it does not necessarily have to be a municipality that treats the firms' effluent.

[7] See appendix D for a detailed account of how municipalities go about setting a charge.

As stated above, charge 2 offers the least cost solution to the abatement problem if a C.T.A. can do at least some of the treatment at a lower cost than the firms. This can be illustrated by comparing the costs of reducing the strength of the effluent to the predetermined level using charge 2, to those under the other methods examined thus far.

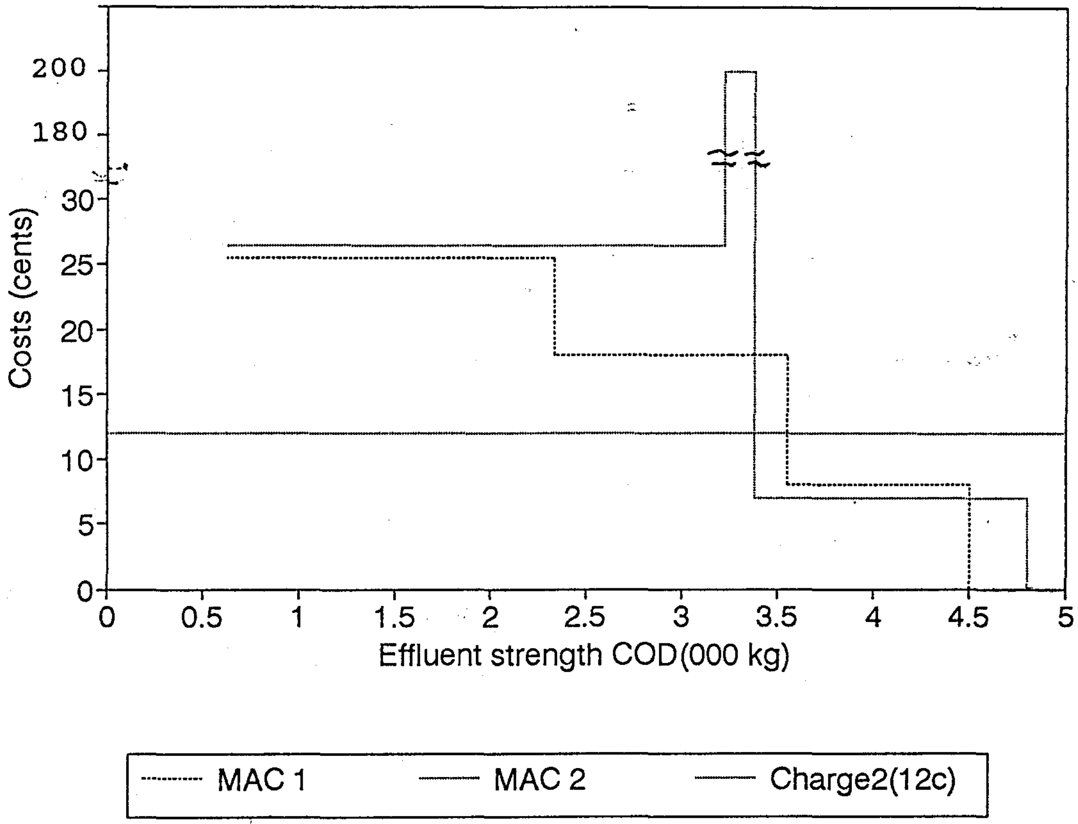

Figure 6.6: The use of charge 2 to achieve a predetermined level of effluent discharge.

In figure 6.6, charge 2 is used, set by a C.T.A. based on its cost of treatment. Assuming a charge of 12c per kg of COD, from figure 6.6, it can be seen that both firm 1 and 2 would undertake only stage 1 of their respective treatment processes. From table 6.1, Firm 1 would reduce its effluent strength by 950kg to 3 550kg and firm 2 would reduce its effluent by 1 424kg to 3 376kg. The total amount of effluent remaining would be 6 926kg. The remainder of the treatment necessary to reduce the effluent strength down to the predetermined level (i.e. 1 076kg) would be done by the C.T.A. Given that the charge reflects the C.T.A.'s total cost of treatment, it would reduce the effluent to the predetermined standard at a total abatement cost of (1 076 x 12c) R129.12. The cost of reducing the effluent to the predetermined level under charge 2 would therefore be, from table 6.1, the abatement costs of firm 1 (R183.43) + firm 2 (R233.05) + the C.T.A (R129.12) and totalling R545.60.

Note that charge 2 is lower than charge 1 and the price of marketable permits since the C.T.A. can treat at a lower cost than the firms. Indeed, if they were not, the charge would be higher, firms would do all the treatment themselves and the C.T.A. would not exist.

Firms have still treated until their marginal abatement costs are equal to the charge. A charge set in the manner discussed above will have an advantage over charge 1 in so much as it is not set on a trial and error basis. It has the advantage over all other methods of pollution control in that it is the least cost solution to the abatement problem.

The total abatement cost of achieving the predetermined standard of an overall effluent strength of 5 850kg of COD was greatest under a system of standards (R1 546.49), less under marketable permits and charge 1 (R635.34). The least cost solution to the abatement problem was however under charge 2 (R545.60). This must hold as long as the C.T.A can treat at a lower cost than the firms.

If a charge is set based on a central treating agency's costs it would allow for a new type of subsidy to be used. This would entail a subsidised charge. By this it is meant that the charge does not reflect the C.T.A's total cost of treating the two firms' effluent. Firms pay less than they should but the C.T.A. still recoup their costs of treatment because households pay more i.e households subsidise the firms' cost of effluent treatment(see Appendix D). This is clearly not equitable as the cost of the pollution is being borne by someone other than the polluter (i.e. why should an individual who neither produces the commodity, nor consumes it,have to bear some of the cost of the pollution that the commodity causes). It will also not be economically efficient if the subsidised charge is set at a level where firms do less treatment than under a non-subsidised charge. The reason for this is that the firm(s), that could have done some of the treatment at a lower cost than the central treatment agency, will now not do so. This can be illustrated by means of an example and with the aid of figure 6.7.

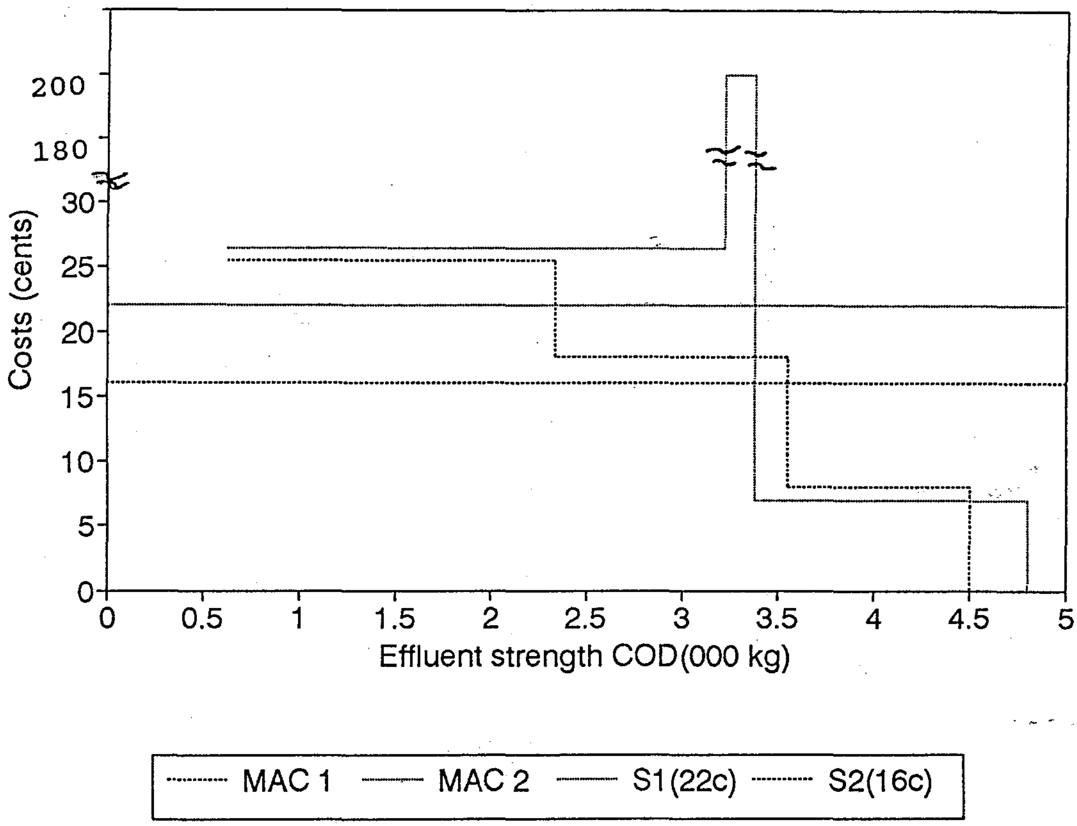

Figure 6.7: The economic inefficiency of subsidy 2.

In figure 6.7, S1 is the non-subsidised charge (22c) and S2 the subsidised charge (16c). As can be seen the firms would do less treatment under the subsidised charge.

Under S1, firm 1 would reduce its effluent strength by 2164kg to 2 336kg. Firm 2 would reduce its effluent by 1 424kg to 3 376kg. The total amount of effluent remaining would be 5 712kg. The remainder of the treatment necessary to reduce the effluent strength down to the predetermined level (i.e. 132kg) would be done by the C.T.A. Given that the charge reflects the C.T.A.'s total cost of treatment, it would reduce the effluent to the predetermined standard at a total abatement cost of (132 x 22c) R29.04. The cost of reducing the effluent to the predetermined level under S1 would therefore be the abatement costs of firm 1 (R402.43) + firm 2 (R233.05) + the C.T.A (29.04) and totalling R664.38.

Under S2, firm 1 would reduce its effluent strength by 950kg to 3 550kg and Firm 2 would reduce its effluent by 1 424kg to 3 376kg. The total amount of effluent remaining would be 6 926kg. The remainder of the treatment necessary to reduce the effluent strength down to the predetermined level (i.e. 1 346kg) would be done by the C.T.A. Given that the charge reflects the C.T.A.'s total cost of treatment, it would reduce the effluent to the predetermined standard at a total abatement cost of (1 346 x 22c[8]) R296.12. The cost of reducing the effluent to the predetermined level under S2 would therefore be the abatement costs of firm 1 (R183.43) + firm 2

[8]Despite the subsidy, the cost of treatment to the C.T.A. remains the same

(R233.05) + the C.T.A (296.12) and would be R712.60.

This means that the total abatement cost of achieving the predetermined level of effluent strength is greater under the subsidised compared to the non-subsidised charge.

6.6. Problems with the theory.

There are a number of problems that arise in the practical application of the theory to the leather industry. These include:

(i) Under a system of charges the theory states that the firms should treat until their marginal abatement costs are equal to the charge set by the authorities. A problem however arises if the charge has been set so that it reflects the C.T.A.'s total cost of treatment. Assume that some firms now find new ways of abating their pollution. Furthermore this new technology allows them to discharge effluent that has a greatly reduced strength and/or volume compared to that when the charge was set. This should, for the firm, lead to a saving on its effluent disposal bill equal to the decrease in the strength and/or the volume of their effluent multiplied by the charge formula.

The charge however was set based on the C.T.A.'s cost of treating a given amount of COD. If this amount was to decrease, it is likely that the average cost of treatment per unit of COD would increase. The reason for this is because the C.T.A's costs of treatment would, in all likelihood, not change but the number of units of COD being treated would decrease. It is therefore possible that you could find the paradoxical situation where a decrease in the strength and/or volume of a firm's effluent could lead to an increase in the charge, reflecting the C.T.A.'s new cost of treatment. This could act as a disincentive for firms to find new abatement technologies because the gains to be made by the firms from the new technologies could be offset by the increase in the charge. This could cause one of the theoretical advantages of charges, i.e. that of an increase in the incentives for firms to find new abatement technologies, to fall away. The same problem obviously does not hold if standards are set in order to decrease the firms' effluent to a predetermined level and have no reference to the C.T.A.'s cost of treatment. Nor does the problem hold for permits.

(ii) According to both the theory and in practice, the profit maximising level of treatment is where the firm's MAC are equal to the charge. The firm's MAC curve is however derived from its total abatement cost curve. If a firm had to terminate treatment at this point (i.e.

where MAC=charge) then its total abatement costs would change and consequently its MAC curve would change. It would therefore end up doing less treatment than it was going to. The reason for this is because the total abatement costs consist not only of the capital and running costs of the pollution abatement equipment but also costs such as transportation, consultancy and installation. These costs would not necessarily change if the firm were to use one less stage of treatment.

(iii) As was mentioned in Chapter 5, great difficulty was experienced in obtaining the necessary data needed to do this study. This included data on the firm's MAC and the reduction in the strength of the effluent after each stage in treatment. These difficulties were encountered because the firm's investigated either did not have the information or were not prepared to disclose it. If it is found that firms in fact do not have this information then it would seem highly unlikely that the theoretically envisaged outcome of firms treating until their MAC curves were equal to the charge, holds in practice.

There may be a number of reasons for this. Leather firms may not perceive the costs of effluent disposal as sufficiently high to invest time, money and effort into doing something about it. Perhaps leather firms are not sufficiently aware of what the costs are. By this it is meant that they are not sufficiently aware of what savings are available to them if they took the time, money and effort to investigate the situation fully. It is however necessary for firms to realise that the costs of effluent disposal are unlikely to decrease. On the contrary, they will in all likelihood become more expensive.

While "stepped" MAC curves may be implicit in the theory, their implications are not made explicit. The "stepped" nature of the MAC curves does however lead to problems which are not readily discussed or indeed acknowledged by the theory. For example;

(iv) In practice taxes, marketable permits, subsidies and for that matter standards are not optimal means of pollution control. It would be possible, with the smooth MAC curves explicit in the theory, to achieve the exact target of 5 850 kilograms of COD discharged per day. In practice however, the target was never exactly achieved. This is because in practice the MAC curves are not smooth but "stepped".

(v) Earlier in the chapter, when charge 1 was examined, it was assumed that the authorities had perfect knowledge of the firms' relevant cost functions. This is obviously highly unlikely to occur in practice. Despite this, the theory claims that it would be still be possible to arrive, through a trial and error process, at the correct charge. Furthermore, while conceding that there are costs involved, these should not offset the benefits to be gained by controlling pollution through the use of charges. This would hold if the firms MAC curves were smooth. It would however, be an almost impossible and very costly task when, as has been found, the curves are "stepped". This can be illustrated by way of an example.

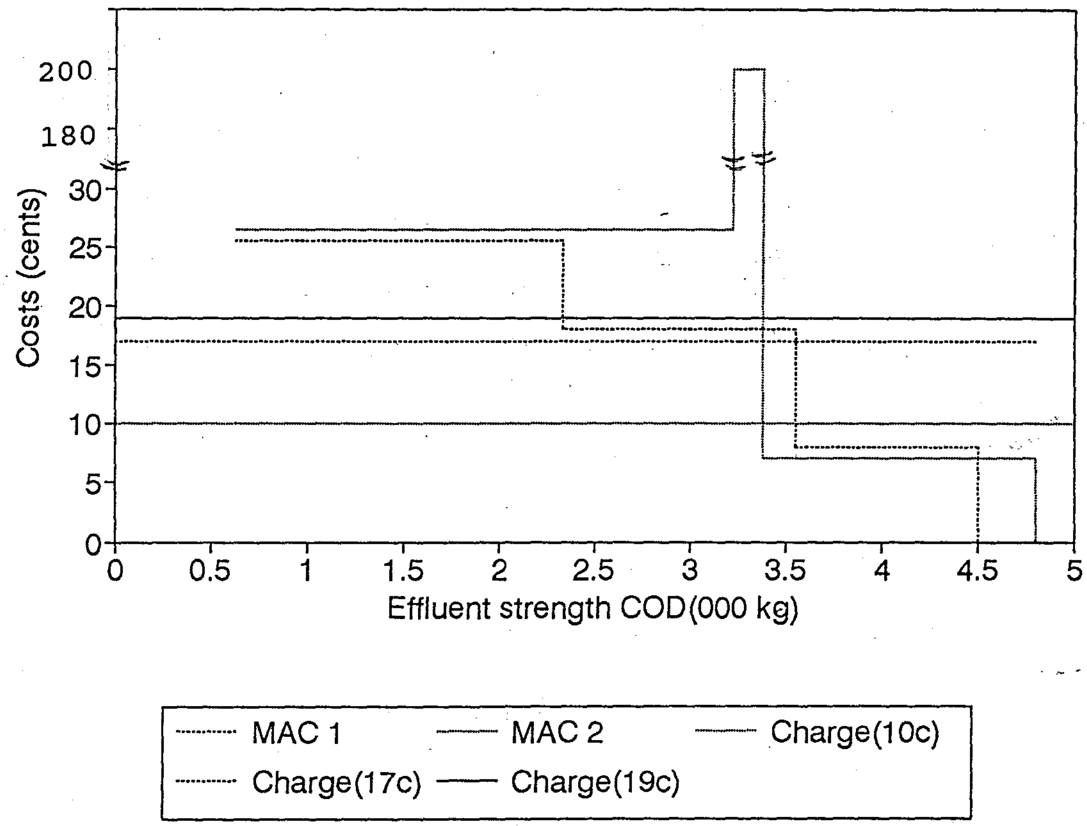

Figure 6.8: The setting of a charge based on a trial and error basis.

Assume in figure 6.8, that the regulating authority decided that they wanted to achieve what they felt was an optimal strength of the firms effluent of 3 000kg of COD and set an initial charge of 10c per kilogram of COD discharged. Firm 1 will respond by installing stage 1 of its treatment process and thereby reducing the strength of its effluent to 3 550kg. The authorities, seeing that the optimal level has not been reached, would increase the charge to say 17c per kilogram of COD. At this price, the firm would continue to do the same amount of treatment. This would mean that the authorities would have to increase the charge further. Assume that they now increased it by a small amount, say 2c to 19c per kilogram of COD. Firm 1 would respond by installing stages 2 and 3 of the treatment process and so decrease the strength of its effluent to 630kg. Therein lies the problem. Depending on where the firm is on the MAC curve, a small change in the charge could lead to large change in the amount of treatment and therefore the strength of the effluent. Conversely a large change in the charge could lead to little or no change in the amount of treatment done. It therefore makes the setting of an optimal charge on a trial and error basis almost impossible. The same would not hold for charge 2 (set on the basis of costs), marketable permits (set at a standard) and standards themselves.

Despite these problems all the methods looked at always erred on the side of too much rather than too little treatment. This is due in part to the "stepped" nature of the MAC curves and in part to the assumption that if the cost of treatment is the same as a charge or the price of a permit, firms will prefer to treat. Economic incentives will further always ensure that abatement is done at a lower cost to society compared to standards.

6.7. The net benefits of treatment

As was stated above, firms should treat until the marginal abatement cost of treatment is equal to the charge. By applying the data to the formula developed in Chapter 4 we can see what the net benefits of treatment are for the individual firm.

Recall that the formula was:

$$NBT = [Pw + Prm_{(1...m)} + Psp_{(1...m)} + Ec^* + Cs^*] - [K + L_{(1...m)}]$$

Where:	NBT	=	Net Benefit of Treatment
	Pw	=	Value of recycled water
	$Prm_{(1...m)}$	=	Value of recycled materials
	$Psp_{(1...m)}$	=	Value of secondary products
	Ec*	=	net saving on municipal effluent charge
	Cs*	=	Net saving on solid waste disposal bill
	K	=	Capital cost of treatment plant
	$L_{(1...m)}$	=	Non-capital input costs of a treatment plant

Given the data available to us, the only part of the formula that can be used is $[Ec^*] - [K + L_{(1...m)}]$. Despite this, it will still serve to show that once firms are charged for the effluent that they generate, benefits may accrue to them if they undertake treatment. It further reinforces the reason why, when the cost of pollution is internalised, firms undertake treatment in order to reduce pollution and hence cost. It will further show that in order to maximise the total benefits of treatment, firms should treat until the net benefits of treatment are zero. If however, given the nature of the treatment and hence the shape of the MAC curves, the NBT should equal zero in between two stages then the firm should treat to the stage before the NBT will be equal to zero.

Assume that the cost of effluent disposal is 18.03c per kilogram of COD (this could be a charge or the price of marketable permits). Looking first at firm 1. If, faced with the cost of effluent disposal assumed above, firm 1 does not treat, it will face a cost of (4500x18.03c) R811.35.

If however, the firm undertook stage 1 of the treatment, its net benefits of treatment would be as follows:

$$
\begin{aligned}
NBT_1 &= [Ec^*] - [K + L_{(1...m)}] \\
&= [R811.35 - (3\ 550kgx18.03c)] - [R71.76 + R7.92] \\
&= [R811.35 - 631.05] - [R79.59] \\
&= R180.28 - R79.59 \\
&= R100.69
\end{aligned}
$$

Firm 1's NBT for the other stages may be worked out in the same way and are as follows: $NBT_2 = 0$

$NBT_3 = (-)\ R126.95$

It would therefore be economically beneficial for firm 1 to undertake stages 1 and 2 of treatment but not stage 3. This can be shown graphically by plotting the net benefits of treatment on the Y axis and the stages of

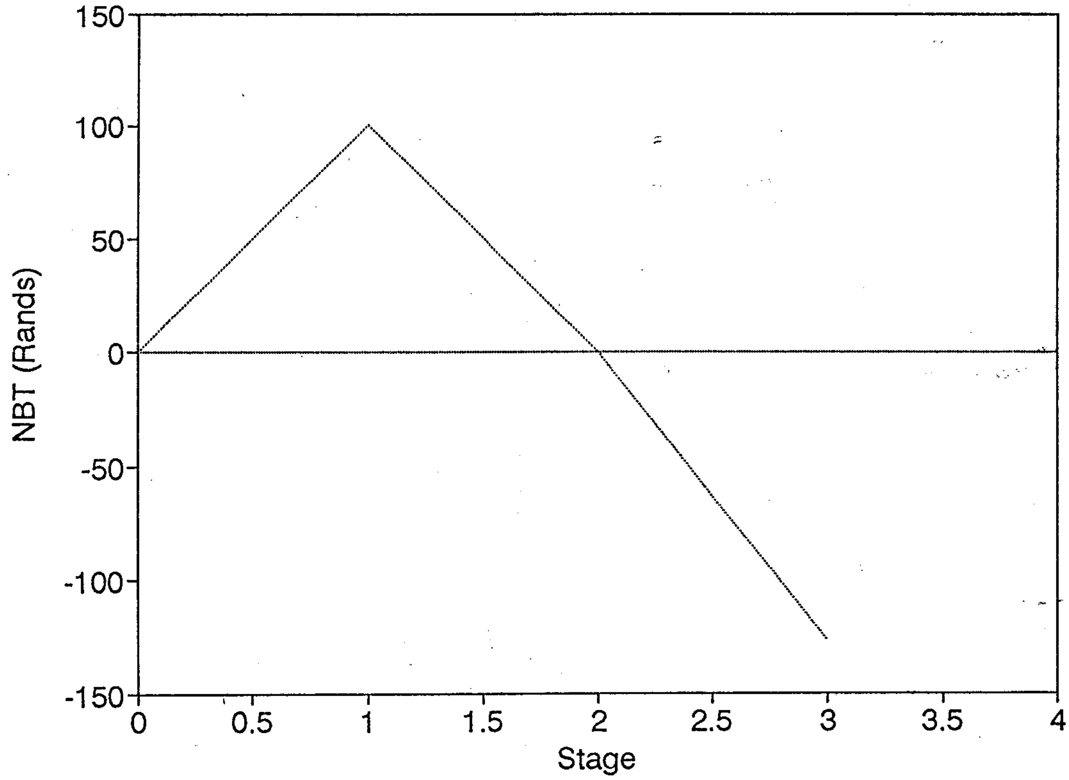

Figure 6.9: Net benefits of treatment for firm 1

The total benefits of treatment (TBT) accruing to a firm are the total savings gained from treatment minus the total costs of that treatment. They will be maximised when the firm undertakes treatment to the stage where its NBT equals zero, or, given the shape of the MAC curves, when the firm undertakes treatment to the stage before its NBT will be equal to zero. The total benefit of treatment for firm 1 will be as follows:

TBT_1 = R100,69

TBT_2 = R298.45

TBT_3 = R(-) 36.22[9]

The total benefits of treatment can be shown on a graph by plotting the TBT on the Y axis and the stages of

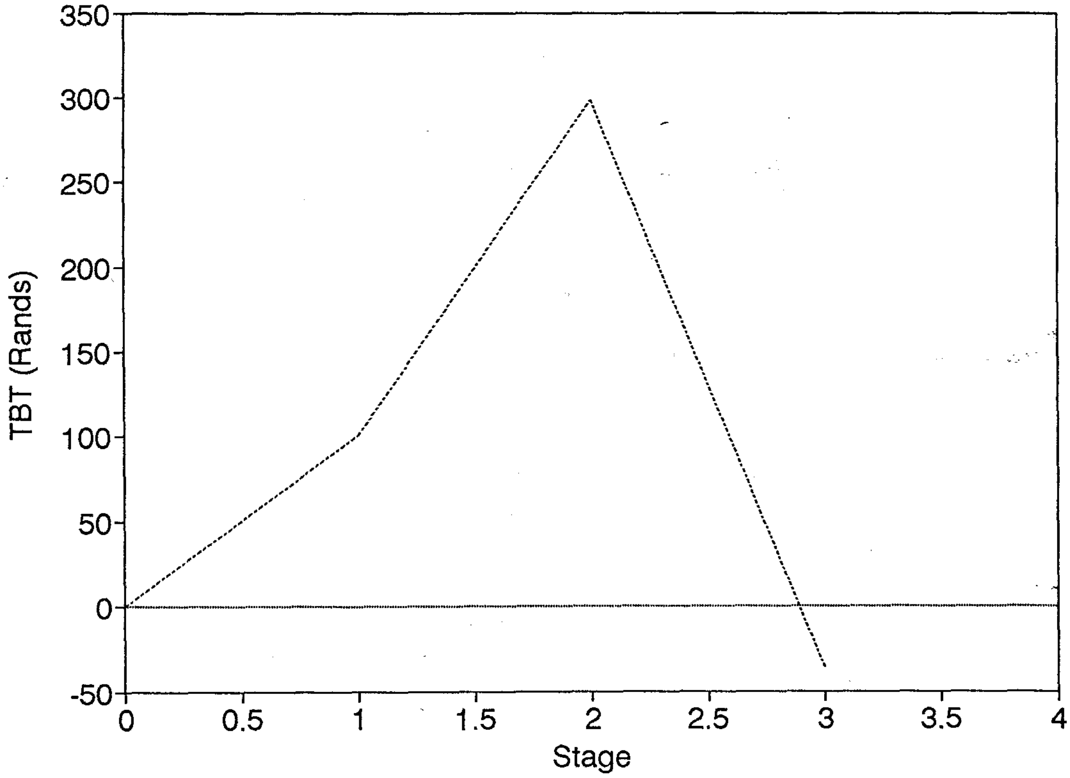

Figure 6.10: Total benefits of treatment for firm 1

As can be seen from figure 6.10, the TBT are maximised when the firm treats until their NBT are equal to zero i.e stage 2 in this case.

[9] Figures were obtained from appendix C.

Turning to firm 2. If, faced with the cost of effluent disposal assumed above, firm 2 does not treat, it will face a cost of (4800x18.03c) R865.44.

If however, the firm undertook stage 1 of the treatment, its net benefits of treatment would be as follows:

NBT_1 = [Ec*] - [K + $L_{(1...m)}$]

= [R865.44 - (3 376kgx18.03c)] - [R102.17 + R9.92]

= [R865.44 - 608.69] - [R112.09]

= R256.75 - R112.09

= R144.66

Firm 2's NBT for the other stages may be worked out in the same way and are as follows: NBT_2 = (-) R284.64

NBT_3 = (-) R190.90

It would therefore be economically beneficial for firm 2 to undertake only stage 1 of treatment but not stages 2 and 3. This can be shown graphically by plotting the net benefits of treatment on the Y axis and the stages of treatment on the X axis.

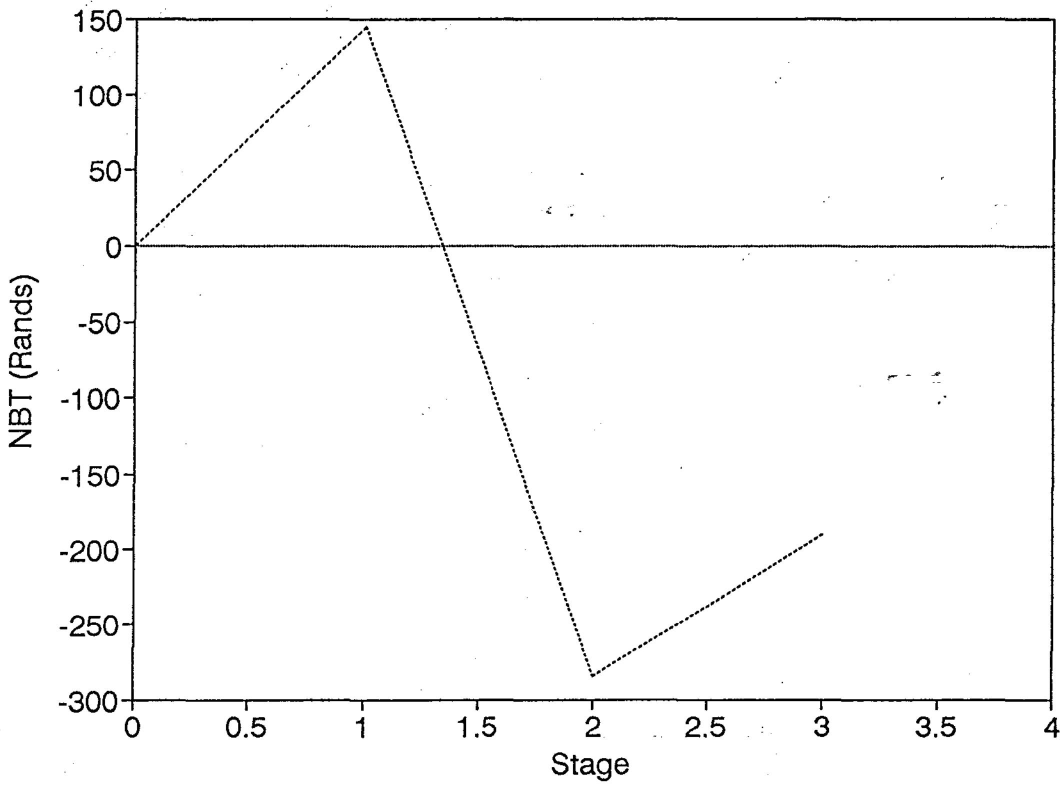

Figure 6.11: Net benefits of treatment for firm 2

As can be seen in figure 6.11, firm 2's net benefit of treatment are equal to zero in between stages 1 and 2. As mentioned above, the firm should then only do stage 1 of treatment.

In the case of firm 2, The TBT be maximised when the firm undertakes treatment to the stage before its NBT will be equal to zero. The total benefit of treatment for firm 2 will be as follows:

TBT_1 = R144.65

TBT_2 = (-) R158 02

TBT_3 = R(-) R331.18[10]

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[10] These figures were obtained from appendix C

These are illustrated in figure 6.12.

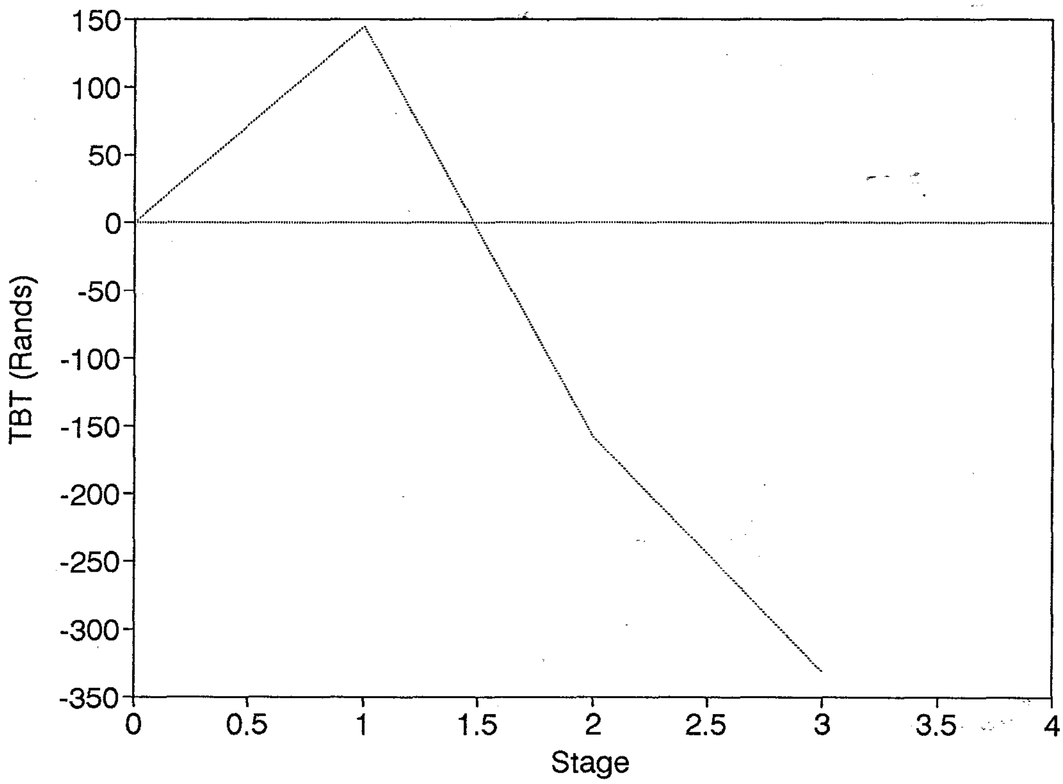

Figure 6.12: Total benefits of treatment for firm 2

Recommendations and conclusions, based on the practical application of the data to the theory, are discussed in the next chapter.

APPENDIX D

Municipal charges

Where a municipality agrees to accept the discharge of industrial effluent into its sewerage system, the municipality is classified under the provisions of the Water Act (No. 54 of 1956) as a user of water for industrial purposes, and must purify its eventual discharge to meet the consent conditions for this discharge, and\or the relevant standards given in table 2.3 (discharge to public streams) and\or to those standards governing marine disposal (WRC, 1987:3).

The standards are set down by the authorities (in this case the Department of Environmental Affairs). There are two standards, either a general standard or a specific standard, depending on what the water that the purified effluent is discharged into is going to be used for and on the water stream that it is discharged into. Standards ensure that there is no damage done to the flora and fauna of the water source and do not differ nationally (i.e. are the same for all areas and do not yet take into account the different assimilative capacities of various bodies of water).

Municipalities propagate their own standards for acceptance of industrial effluent into the municipal sewerage system. These standards are designed to ensure that the "municipal sewerage works are not overloaded or deleteriously affected to the detriment of other municipal users or the final effluent discharge quality" (WRC, 1987:3). The standards of effluent accepted by municipalities differ from municipality to municipality depending on the age, nature and size of the municipal treatment works, on the amount of effluent that the treatment plant has to process and on the standards that the municipality has to meet for their discharge (Kerdachi, 1993).

Municipalities enter into contracts with firms which allows firms to discharge certain amounts and types of effluent. Firms sign a contract with the municipality on what they can and cannot discharge, in terms of volume, strength and type of effluent. If a firm exceeds the parameters the contract is broken and becomes a legal matter (Kerdachi, 1993).

For the Polluter Pays Principle to hold, the tariff set by the municipality for the effluent that they accept should be directly related to the cost of treatment. For the municipality the cost of effluent treatment is made up of treatment and reticulation costs.

Treatment costs are made up of the total amount spent on inputs (eg. wages, chemicals, electricity etc. equal to Rx) and the interest and redemption charges on loans for capital equipment (equal to Ry). The total cost therefore equals Rx + Ry. If the total flow of effluent equals z, treatment costs are equal to (Rx + Ry)/z to give the rand per kilolitre cost to treat the effluent (Kerdachi,1993).

Reticulation costs are the costs of transporting the effluent from its source to the municipal treatment works and is the same for all users of the municipal treatment works i.e. it is geographically unbiased. This means that firms pay the same per kilolitre, regardless of their distance from the treatment works. The costs will be made up of the total amount spent on infrastructure (eg. costs of pipes, maintenance, installations, wages etc equal to Ra) and the interest and redemption on infrastructure (equal to Rb) If the total flow of effluent to the works equals c, the costs of reticulation will equals (Ra + Rb)/c to give the rand per kilolitre cost of transporting effluent. This cost is totally flow related and has nothing to do with the strength of the effluent (Kerdachi, 1993).

The principle of effluent tariffs are therefore based on the cost per kilolitre of conveyance plus the treatment cost.

The conveyance cost can be calculated accurately. The treatment costs are generally worked out by measuring at the amount of carbon present in the effluent. This can be done by using a number of measures. For example municipalities can measure the permanganate values (PV) or the oxygen absorbed (OA) levels or the chemical oxygen demand (COD) of the effluent. All give the strength of the effluent by measuring the unstabilised carbon present in that effluent. Municipalities take the flow of effluent and multiply it by the strength of effluent (ml x mg/l) to get the amount of kilograms of, say OA, arriving at the plant. This mass of unstabilised carbon is used as a basis for charging firms for the effluent that they discharge because the cost to the municipality for the purification of effluent depends on the mass of unstabilised carbon that has to be treated. The strength of effluent for industry is normally determined by monitoring at source by way of random samples (Cooper, 1993).

The volume of effluent discharged by a firm is worked out by taking the amount of raw water that is sold to a firm minus a given daily allowance for domestic use (eg. toilets, wash basins etc) of fifty litres per head per day minus the amount of water retained in the production process of the firm (Cooper, 1993).

A typical municipal charge formula should therefore be the charge per kilolitre of effluent treated that is equal to the conveyance cost and the treatment cost where the treatment cost equals OA/F, i.e. a measure of the strength of the effluent, OA, per unit cost to the municipality of treating the effluent (Cooper,1993). A municipality could increase or decrease the overall effluent charge by either increasing or decreasing the conveyance charge or the amount of the cost factor (F).

It has been shown that in theory the municipality should set the effluent charge according to the cost of treatment and reticulation of a given quantity and quality of effluent. For the Polluter Pays Principle to hold the municipality should charge firms 100% of their treatment and reticulation costs. Whether or not this holds in practice is a debatable point. For example, data from a municipality shows how the percentage of costs reclaimed by this municipality from firms increased from 30% of the cost in 1979/80 to 72% in 1989/90. This is shown in table D1

Table 6.2: Comparison of actual income and treatment costs for industrial effluent for a municipality

Year	Total treatment costs (c/kl)	Actual income (c/kl)	% of treatment costs recovered
1980/81	35.5	12.5	34
81/82	42.6	26.2	40
82/83	52.6	21.0	36
83/84	84.7	34.0	44
84/85	87.0	37.0	45
85/86	120.1	51.0	48
86/87	120.9	50	47
87/88	123.4	62.5	50
88/89	123.8	75.8	60
89/90	134.2	96.6	72

The difference between the actual income from industrial effluent and the total cost of treating that effluent is made up by subsidization from domestic households. As has been shown, it is important that effluent charges are based on the Polluter Pays Principle if they are to be used as an economically efficient and equitable means of controlling pollution.

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The environmental economic theory discussed in chapter 3 suggested that the most economically efficient and equitable means of controlling the pollution generated by the leather industry was through the use of economic incentives rather than standards. The reason was that it offered a least cost solution to the abatement problem.

Regardless of which method of controlling the leather firms' pollution is chosen, it would entail the firms doing some treatment of their effluent. The only exception would be if, under charge 2, the C.T.A. could do all of the treatment at a lower cost than the firm. The potential costs and benefits of treatment were examined in chapter 4. The potential benefits included a reduced effluent disposal bill and the reuse or resale of recycled raw materials, water and secondary products. The benefits of recycling would accrue not only to the firms in the form of increased revenues, but to society as a whole. The reason for this is that less virgin raw materials are used. This would be especially true for water. Furthermore, recycling would be encouraged, if economic incentives were used to control pollution, because it would be made more economically attractive.

The question of how much treatment an individual firm should undertake was addressed by using a formula, viz, $NBT = [Pw + Prm_{(1...m)} + Psp_{(1...m)} + Ec^* + Cs^*] - [K + L_{(1...m)}]$ which was developed to aid firms with this decision. While data was not available for all the components of the formula, there was sufficient to show that in order to maximise the total benefits of treatment, individual firms should treat until the net benefit of treatment is equal to zero.

In order to see whether the theory held in practice it was necessary to apply data, relevant to the leather industry, to the theory. The collection of this data however, proved to be the most difficult aspect of the study. The reason for this was that the leather firms investigated had only a vague idea of what their total costs of treatment were. Furthermore, they did not have a detailed account of either the costs, or the reduction in effluent strength, of each stage of treatment.

The above problem was overcome by using the treatment process of 2 hypothetical firms outlined in a study by the Water Research Commission (WRC, 1987). These were chosen because they gave a detailed account of the reduction in effluent strength after each stage of treatment. The costs were obtained by breaking the treatment process down into its various components. The costs of the civil components were obtained from a civil engineer, the mechanical costs from the commercial suppliers of the plant equipment. The running costs, which were found to consist of the electrical usage of the various mechanical components, were obtained from the Port Elizabeth Municipality.

Armed with information on the costs and reduction in effluent of each stage of treatment it was possible to derive the total and marginal abatement cost curves for the two hypothetical leather firms. This data was then applied to the theory discussed in chapter 3 in order to ascertain whether the theory would hold in practice. It was however necessary to assume that the 2 firms made up the leather industry, that the strength of the effluent was measured only by its chemical oxygen demand (COD) and that when the cost of treatment was the same as a charge, subsidy or the price of a permit, firms would prefer to treat.

While it was found that economic incentives did indeed offer a lower cost solution to the abatement problem when compared to a system of standards, marketable permits would be the most economically efficient method because they do not include the search costs associated with the setting of a charge or subsidy based on a trial and error method.

It was further found that the pollution generated by leather firms is controlled by means of charges. These charges however differ significantly from those discussed in the theory. They were based on a central treatment agency's (C.T.A.'s) cost of treatment, so as to get firms, in conjunction with the treatment agency, to reduce the effluent to a predetermined level. A charge set in this manner was called charge 2 in order to differentiate it from the charge envisaged by the theory, which was now referred to as charge 1. It was found that if a central treatment agency could do at least some of the treatment required at a lower cost than the firms, then the charge, under charge 1 and market permits, would be greater than charge 2, so as to take into account the firms higher marginal abatement costs (i.e. higher than the C.T.A.'s cost). Firms would therefore have had to do more treatment themselves at a higher cost. Charge 2 therefore has the advantage over all other incentives that, as long as there is a C.T.A. that can treat at a lower cost than the firms, it will be the *least* cost solution to the abatement problem. Charge 2 also has the advantage over charge 1 that it is not set on a trial and error basis. Charges 1 and 2, subsidies and marketable permits will be equivalent when the C.T.A. does no treatment.

Where policy options are equivalent policy makers should always opt for marketable permits. The reason for this is because marketable permits offer the same cost minimising solution to pollution abatement that charge 1 and subsidies do, but with a number of added advantages. They reduce the uncertainty and adjustment costs associated with a charge that is not based on the municipality's costs of treatment, they require less intervention and administration by the authorities, take into account the effects of inflation and economic growth, automatically adjust to new entrants and allow standards to be varied with comparative ease.

The use of a charge based on a central agency's costs would allow for a new type of subsidy to be used. This would entail a subsidised charge for firms with the C.T.A. recouping their costs of treatment by making households pay more. While this is clearly not equitable, it was also found to be economically inefficient if the subsidised charge was set at a level where firms would do less treatment than they would have under a non subsidised charge. The reason for this was that the firm(s), who could have done some of the treatment at a lower cost than the C.T.A., would now not do so.

It was found that a number of problems arose with the theory when it was applied to a practical problem. These included the fact that the firms marginal abatement cost (MAC) curves were not linear but "stepped". Given the "stepped" nature of the MAC, the setting of the correct charge on a trial and error basis was even more difficult than the theory envisaged. Furthermore, it meant that it was almost impossible to reduce effluent to an optimal level. This however, was found to hold true for all methods of pollution control. Despite this, abatement always erred on the side of treatment and was still done at a lower cost when controlled by means of economic incentives and at least cost when charge 2 was used.

Other problems were that if firms, as the theory suggests, terminated treatment at the stage where their marginal abatement costs equalled the charge, their treatment costs would change by more than just the capital and running costs of the forgone treatment. This could lead to firms treating less than the theory envisaged.

Furthermore, where charge 2 was used, a decrease in the firms' strength or volume of effluent, in response to the incentive could in fact lead to an increase in the charge. This could adversely affect the incentive that charges offer in respect of firms finding new and improved methods of pollution abatement. It was also suggested that if the firms investigated did not, as they claimed, have information on the cost of their treatment or on the reduction in effluent strength after each stage of treatment, that it was highly unlikely that the theory held in practice. This is meant in the sense that firms were not responding in the manner envisaged by the theory, i.e. treating their effluent until the marginal abatement costs of treatment equalled the charge.

7.2 Recommendations.

Given all of the above a number of recommendations can be made. These recommendations are applicable for the control of all industrial effluent. Furthermore, the problem of pollution is not going to go away. If anything it is going to get worse. The same holds for the availability of raw materials, especially water. The use of economic incentives in controlling pollution has enormous potential, yet in practice is hardly used. What is therefore needed is to start moving away from the purely theoretical towards a practical application of that theory. This is important for a number of reasons. It would make the idea of using economic incentives more appealing to policy makers. Furthermore the theory is not tailor made to be practically applied as it is to all industries. There is therefore a need for more research to be done into different industries to see where and how it can be practically applied. Furthermore the feasibility of having central treatment agencies for other industries and other forms of pollutants needs to be explored. In attempting, in this study, to apply environmental economic theory, a number of shortcomings of the theory were highlighted. Similar studies may therefore help refine the theory so that it can better take account of the practicalities of pollution and pollution control.

Given the superiority of charge 2 over the other forms of incentives it is recommended that, where technically feasible and economically viable, use should be made of central treatment agencies. If the C.T.A is able to do all of the treatment at a lower cost than firms then there is no economic reason why they should not do so. Because a charge is used there would still be an incentive for firms to find new and improved ways of controlling their effluent. Furthermore C.T.A'S do not necessarily have to be municipalities. There may be scope for private firms, especially in the light of the savings to be made under charge 2, to provide the service. This option should perhaps be explored more.

Where the central treatment agency's plant has a limited capacity, that is it can only cope with a certain maximum strength or volume of effluent, a combination of marketable permits and charge 2 should be used. This would entail marketable permits being issued for the maximum capacity of the plant and charge 2 being used for any effluent discharged. This would result in firms abating pollution in terms of the rules of marketable permits and then discharging the effluent to the C.T.A. under the rules of charge 2. This would ensure that abatement is done at the least cost to the firms and to society as a whole. It would further ensure that the upper limit on the C.T.A. plant is not exceeded by using the least cost solution available. Furthermore, by using marketable permits they would automatically regulate the impact of new entrants so that the capacity of the plant is not exceeded.

Where it is not technically feasible or economically viable to have a central treatment plant then, given their advantage over other forms of control, marketable permits should be used.

One of the assumptions made in Chapter 6 was that firm's effluent strength was measured by its COD and that other pollutants were not taken into account. In reality the municipalities not only set a charge based on the strength and volume of the firm's effluent, but also list a number of parameters, for other pollutants, within which the firm's effluent must comply. While firms are not charged for these pollutants, they have to treat their effluent so that it conforms to the parameters.

Municipalities would be better off if they used economic incentives to reduce the effluent to acceptable strengths. Given the number of parameters, a system of charges would prove to be very complex and cumbersome. A different charge would have to be worked out, based either on the municipality's cost of treatment or on a trail and error basis, for each and every parameter.

A far simpler method would be for the authorities to restrict the strength of the effluent to the parameters directly by issuing permits. As has been shown this would lead to the effluent being abated at a minimum cost to society. Furthermore, the complexities of a system of charges discussed above would fall away. Once the authorities have issued the permits the problem of the price would be settled in the market.

The above point assumes that there is a large enough range of polluters to make trade in permits feasible and likely. This is deemed likely because although it has been assumed that only two firms make up the leather industry, it is envisaged that if economic incentives are used to control pollution they would not be used only for the leather industry, but for all industries. This should be feasible despite the fact that effluent from various industries are likely to have different characteristics. For example, all water borne effluent will have a chemical oxygen demand (COD) value or contain settleable solids. If there is still no trading then the authorities could try and encourage it, for example, by holding back a certain percentage of the permits. This would have the added advantage of stopping established firms keeping out newcomers by hoarding permits (The Economist, 1990: 46).

If this is not the case then , given the complexities that a system of charges would entail, it is recommended that the authorities continue to set parameters in the current fashion.

The difficulty experienced in obtaining data, from the firms investigated, on the costs and benefits of treatment would suggest that these firms are not responding to the economic incentives in the manner that the theory suggests. If this is indeed the case then it is recommended that firms should be educated on their treatment options and how they could best respond to the cost of effluent disposal.

Furthermore this study has shown that there are a number of treatment options open to firms in the leather industry. The economic viability of these options were not explored for the simple reason that no firms could be found that were undertaking any of them and so no data was available. Research into this area is therefore both desirable and necessary. A wider use of economic incentives could well add impetus to this research. While this may prove to be uneconomical for an individual firm, an institution such as the Leather Industries Research Institute (LIRI) , which serves the industry, is ideally placed to explore such avenues.

At present the discharge standard for all water borne effluent is the same regardless of location. A truly optimal level of pollution abatement should however be based on the assimilative capacity of the various watercourses. This would differ from location to location. Research therefore needs to be done on what these various assimilative capacities are. The results of these studies could be used to work out location specific discharge standards which should be reflected in the cost of effluent disposal.

In conclusion the theoretical promise of the use of economic incentives as a low cost solution to the abatement problem would, in this instance, seem to hold in practice. While it is hoped that this study will play a small part in encouraging their wider use, it is both necessary and important that further research be done in this field. This is especially true in the case of the viability, both technically and economically, of central treatment agencies for all types of pollutants and industries, the feasibility of the use of economic incentives for other industries and the potential of recycling and/or reuse of materials, currently discharged as waste, both in the leather and other industries. As was mentioned above, policy makers may be more inclined to consider the use of incentives to control pollution if it can be shown that they can solve practical problems in an equitable and economically efficient manner.

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