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THE ENVIRONMENTAL CAPACITY CONCEPT AND THE PRECAUTIONARY PRINCIPLE.

by

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ABSTRACT

The two concepts of "environmental capacity" and the "precautionary priciple" are central to the thinking of different groups in various countries about the use of the environment for the release of effluents and wastes. The marine environment has a capacity to tolerate some disturbance without unacceptible change, and it is this which has been referred to as its "assimilative capacity" by Cairns, or more recently as the "environmental capacity" by GESAMP. The "precautionary priciple" is in part a response to the failures of the use of environmental capacity, focussing on the need for more effective compliance monitoring and the problems of establishing causal links between contaminants and their effects. Proponents of the precautionary principle require greater care in the use of the environment by requiring those who control effluents to demonstrate they will be harmless following release.

The two approaches are critically examined. Two suggestions are proposed that address key questions: First a set of operational criteria for rapidly establishing causality are suggested that would provide a basis for control action against contaminant suspected of having deleterious effects, that is short of absolute scientific proof. Second, it is suggested that one way to conserve the capacity of the environment to accept, degrade, recycle or sequester wastes without unacceptable damage is to value it as an economic resource whose use has to be paid for by those who use it at a price that relates to other routes of disposal.

1.INTRODUCTION

In recent years two concepts related to pollution management have become widely discussed and debated. The "environmental capacity" (=assimilative capacity) of receiving waters for effluents and emissions, is considered to allow the utilisation of the ability of receiving coastal waters to receive effluents without causing unacceptable harm (Pravdic,1985). Then there is the "precautionary principle", which its proponents set in apposition to what they refer to as the "permissive principle". It has been put forward as a strategy affording greater environmental protection, which purports to be a preferable alternative. (Johnston and MacGarvin, 1987).

The purpose of this paper is to examine objectively the concepts of "environmental capacity" and the "precautionary principle" both as scientific and practical approaches to releasing effluents into the marine environment, given the social, economic and other non-scientific factors which play a part in management decisions.

Since the main advocates of these concepts are often in opposition in discussing environmental matters , and the ideas in question have been debated as alternative approaches (ten Hallers-Tjabbes and Bijlsma, 1989), there is good reason to also consider whether they are mutually exclusive. The impression that the proponents of the precautionary principle create is that some quite different strategy is required for improved protection of the marine environment, due to the historical failures of the concept of environmental capacity. Is this approach flawed, or is the knowledge base used to implement it inadequate? Are they fundamentally different concepts and must therefore be considered as alternative strategies, or could they be integrated into some broader and preferable approach?

2. ENVIRONMENTAL CAPACITY

The "assimilative capacity" concept was initially proposed by Cairns (1977), adopted in the US (Goldberg, 1979), and by GESAMP (Pravdic, 1985), then in the UK (Portmann and Lloyd, 1986) under the more appropriate name "environmental capacity". The concept has been accepted widely by regulators and others as a basis for managing the release of wastes and effluents into the marine environment, which by definition purports to do so without unacceptable harm.

The assimilative capacity concept was first proposed by Cairns (1977), to mean the ability of an ecosystem to cope with certain levels of waste discharges, without suffering any significant deleterious biological effects. Several definitions were put forward at the Crystal Mountain Workshop (Goldberg, 1979), and while there was some disagreement, a concensus definition was proposed that assimilative capacity is "the amount of material that could be contained within a body of seawater without producing an unacceptable biological impact".

The definition of "environmental capacity" given by GESAMP (Pravdic, 1985), and quoted by Portmann and Lloyd (1986), is "a property of the environment, defined as its ability to accommodate a particular activity, or rate of activity, without unacceptable impact." The concept is based on three premises given by Pravdic, and quoted here in full:

1. that a certain level of some contaminants may not produce any undesirable effect on the

marine environment and its various uses;

2. that each environment has a finite capacity to accommodate some wastes without unacceptable consequences, and that

3. such capacity can be quantified, apportioned to a certain activity and utilized.

The concept is ecotoxicological, in relating chemical contaminants to their possible toxic effects on marine biota, and is intended primarily to protect the capacity of the environment to sustain biological processes. The concept itself is essentially neutral; it does not favour either side in the environmental debate, except in the assumption that the marine environment **has** a capacity to assimilate **some** contaminants. However small it may be for some especially toxic substances, this is a demonstrable fact. The question is which contaminants can be assimilated and how much?

The concept incorporates the assumption that the use of environmental capacity should not have unacceptable consequences. While the level of environmental protection is entirely flexible, in that everything hinges on the level of **acceptability**, the conflicting requirements of environmental protection and waste disposal depends crucially on the subjective assessment of acceptability (Stebbing and Harris, 1988). This is where the debate should be focussed, rather than on the worthiness of the concept itself, in that criteria of acceptablity can be strict or as lenient, permissive or constraining. It is accepted that coastal and estuarine waters may have no capacity to assimilate the most toxic agents, such as tributyl tin (Portmann and Lloyd, 1986).

Goldberg (1983) has posed the question as to is what constitutes an "unacceptable" impact of pollutants on the marine biosphere. This must be considered on a case by case basis because of the considerable variation in the capacity of receiving waters and the biota at risk. Its use should, at the very least, not have a deleterious effect on those biological processes that contribute significantly to environmental capacity by degrading and recycling contaminants, because biological change would be accelerated by arresting processes that contribute to environmental capacity (Stebbing and Harris, 1988).

"Environmental capacity" is therefore not a "polluters charter" nor is it an environmantalists ideal, but it is a concept whose implementation requires knowledge and understanding of the flux and behaviour of contaminants in the marine environment. However, this knowledge is not always adequate for the accurate measurement of the environmental capacity of a water mass, so errors are made.

A corollary of the environmental capacity concept is that its use is controlled by the regulatory authorities, who issue consents to discharge on the basis of the calculated environmental capacity. Similarly it falls to the regulatory authorities to establish by their compliance monitoring activities where contaminants do cause "unacceptable harm" and to take action to control them.

3. "PRECAUTIONARY PRINCIPLE"

Environmental groups advocate the use of the "precautionary principle (Johnston and MacGarvin, 1987) as an alternative to the "environmental capacity". Its origins lie in the German concept of *Vorsorgeprinzip* first put forward in the 1970s, and incorporated in the Ministerial Declaration following the Second International Conference on the North Sea in London (1987). The principle is not adequately defined, even in papers dedicated to the subject (Dethlefsen, 1986), yet it was recently referred to as "... an important development in scientific thinking which increasingly underpins international environmental policy" (Johnston and Simmonds, 1991).

The Ministerial Declaration following the 2nd International Conference on the Protection of the North Sea (1987) incorporated the precautionary principle. The Declaration agreed to:

" ..accept the principle of safeguarding the marine ecosystem of the North Sea by reducing polluting emissions of substances that are persistent, toxic and liable to bioaccumulate at source by the use of best available technology and other appropriate measures. This applies especially when there is reason to assume that certain damage or harmful effects on the living resources of the sea are likely to be caused by such substances, even where there is no scientific evidence to prove a causal link between emissions and effects ("the principle of precautionary action")."

The precautionary principle, has apparently not been rigorously defined; its proponents depending on associations with everyday terms like "caution", and strategies by which people anticipate, avoid, reduce and remove risk from their lives (Johnston and Simmonds, 1991). While it is clear what is meant, it claims to be a development in scientific thinking, it should be examined as such.

To some extent the meaning of the concept is clarified by the context in which it occurs in the Ministerial Declaration (1987). The intention is that there may be reason to act in controlling some contaminants in the absence of proof of causality between emissions and deleterious biological effects. Concern is rightly expressed that, where consent procedures fail - perhaps because the environmental capacity is overestimated or toxicity underestimated - and damage to biota in receiving waters is the result, control of a suspect contaminant for which there is evidence should not wait for proof of causality. There should be criteria that provide a basis for action that do not require proof in the strict sense, so that control can be introduced more quickly to restrict environmental damage. Suggestions for a set of operational criteria for causality that might be more rapidly applied, are considered below (see Section 5).

An important corollary of the precautionary principle is a proposed change in the burden of proof, such that those who propose emissions have to demonstrate that their effluents are safe, in that there would be no liklihood of harm resulting from their release into the marine environment. It is in part a response to the fact that absence of evidence now for the toxic effects of contaminants, is no proof that such effects are not occurring, and will become apparent in the future. Historically a number of contaminants thought harmless and released into the environment have proved to be toxic (eg TBT). However the requirement of proof of harmlessness prior to release is not a workable concept, as will be shown below.

4.VALIDITY OF THE CONCEPTS

There are certain prerequisites that scientific statements or premises must satisfy to be accepted as such. To paraphrase Popper (1959), a genuine scientific statement must be capable of conclusive verification; in other words, if there is no way to determine whether a statement is true, then that statement has no meaning, for the meaning of a statement is its method of verification.

To be a valid concept, "environmental capacity" has to be shown to exist and must be measurable with sufficient precision that the capacity can be used without risk of causing "unacceptable harm". The concept implies that compliance monitoring must be adequate to measure the degree of harm caused, so that its acceptability can be judged.

It is recognised that the marine environment has a capacity to dilute, to disperse and sequester contaminants, there are many chemical and biological processes that degrade and detoxify contaminants, and biological systems themselves are adapted to metabolise and excrete or bind contaminants. Particulate matter in suspension that is autochthonous or biogenic (seston), scavenges metalliferous and organic contaminants and the substantial filtration capacity of the benthic biota removes them from the water column, deposits them on the sea bed. All these processes must contribute to the environmental capacity of receiving waters, and our understanding of them can be used to predict their capacity to keep concentrations beneath toxicological thresholds. The question is to what extent is our understanding sufficient for that prediction to be accurate, or are the assumptions too numerous?

Those who adhere to the precautionary principle rightly believe that we should not determine what the capacity of the environment is to accept wastes by overloading it. It is obviously not sensible to attempt to establish what are maximum sustainable effluent inputs by exceeding them in the very system we are trying to protect. Nevertheless there is the difficulty of predicting from existing knowledge, in advance of any effluent release, exactly what the capacity of the receiving waters might be. There is not only the question of knowing how contaminants will behave, and how well they might be diluted, but laboratory toxicity data must be extrapolated from the laboratory to indigenous populations in the field. Given the multitude and complexity of the processes involved, it should be asked whether environmental capacity is accurately determinable with current knowledge, or whether we can only use it with confidence with much greater safety margins than those used at present.

The concept of a "mixing zone" around an effluent outfall, as the only area where a biological impact is to be expected has become an unrealistic simplification. The assumption is implied that processes of dispersion and degradation ensure that there are no further biological effects outside the mixing zone. This might be so were it not for those geochemical processes (eg at sea surface and sea bottom, at frontal regions, gyres and turbidity maxima in estuaries) that reconcentrate some contaminants to levels that may exceed toxicological threshold levels by orders of magnitude. A wealth of data now demonstrate that the assumption of continued dilution and dispersion outside the mixing zone is invalid. Those points in the system where contaminants reconcentrate should become the foci of monitoring effort, as unacceptable effects will occur there first.

The precautionary principle encourages more caution in giving consents to discharge to the marine environment, such that contaminants be shown to be harmless. The "burden of proof" would be transferred to the polluter, who is required to demonstrate that an effluent would be without biological effect. It is not possible to demonstrate that a contaminant is harmless, or non-toxic, in the sense that toxicity is as much a function of concentration as it is of inherent toxicity of the agent concerned. Thus even "non-toxic" materials can be harmful in sufficient concentrations. To paraphrase Paracelsus, it all depends on the dose. Conversely "harmlessness" depends as much on the degree of dilution, which is not under the control of the discharger. To prove that some contaminant will be safe or harmless on release into the receiving waters requires more assumptions to be made of its behaviour in the environment, than of its inherent toxicity. Such assumptions may often be safe, but they do not take into consideration the numerous processes now known that may reconcentrate contaminants at biologically active zones and interfaces in the marine environment.

In addition there is the point that it is not reasonable to assume or to demonstrate that any compound upon release into the marine environment will under all circumstances be harmless to all biological forms. It is a universal statement that is simply not testable and therefore inadmissable.

Toxic threshold concentrations are a crucial component of implementing either concept, as they provide the upper limit that concentrations of contaminants in the environment should not exceed to avoid a biological impact. The problems in their reproducability and extrapolation from single species, laboratory acute tests to communities in the field over indefinite periods, are legion. Besides which recent work suggests that under the influence of **sublethal** toxic stress, populations may be expected to decline and die out (Willows pers comm.). Furthermore, there are toxic effects that impair reproductive capacity which may not be lethal, yet extinguish populations (imposex in gastropods induces by TBT).

Whatever the scientific difficulties - and they are diminishing as understanding grows - society is committed to continue to utilise the environmental capacity, and changes in dealing with wastes and effluents can not be implemented rapidly. In the meantime the environment must be better protected by a more cautious use of its capacity to assimilate wastes.

5. THE PROBLEM OF CAUSALITY

The nub of this debate lies in the question of causality and the inadequacy of the methods by which to demonstrate that a contaminant is causing an observed toxic effect in the environment. Popper (1959) tells us that the meaning of a statement is its method of verification. The limiting factor in the effectiveness of approaches to managing marine environmental quality, is the effectiveness of the methods employed to measure water quality and detect those contaminants that depress it.

One approach to establishing causality retrospectively utilises the reciprocal reasoning to that used to avoid toxic effects in anticipation of the release of an effluent. Safe and therefore permissable concentrations are set which aim to avoid toxic effects in the environmnent, by taking laboratory toxic threshold data and calculating the concentration at which no effect would be expected (outside a "mixing zone"). An application factor (Sprague, 1971) is chosen with the intention of ensuring that concentrations in the receiving waters do not exceed toxic thresholds. The reasoning can obviously be reversed, and the assumption made that if environmental concentrations are found to exceed laboratory toxic thresholds, causality is implied.

The issue is difficult because while experimental rigour can be maintained in the laboratory, to consider one variable at a time; in the environment this is impossible. There are always numerous candidate contaminants for any observed biological effect, and natural factors often prevent clear conclusions being drawn from observational data on spatial or temporal distributions of contaminants and their supposed effects. Toxic effects tend to be generalised rather than specific, and even with those rare examples where the toxic effect itself is considered to identify the cause(s), there are always unresolvable questions relating to the degree of specificity. At best current methods are correlative anf therefore ambiguous. Strictly speaking their acceptance requires the elimination of **all** other factors to be certain that the observed effect is due to to the one suspected contaminant alone. In the case of the characteristic shell thickening in oysters and imposex in dog whelks the evidence for tributyl tin (TBT) was overwhelming, but in the strictest sense the case for these effects as specific indices is not conclusive, since other untested contaminants may also induce the same effects. Thus while we are certain that TBT will invariably induce these effects, there remains the possibility that other compounds may also be capable of causing the same effect. The case for the **absolute** specificity of a response is virtually impossible to establish.

A number of new techniques are becoming available where the response itself, to a greater or lesser extent, identifies the class of contaminant(s) that caused it. These have become known as "biomarkers" and are typically indices at the biochemical or molecular level (eg MFO and metallothionein induction). Developments in the toxicological interpretation of tissue burdens; physiological indices of toxic stress linked to QSAR methods, are providing another means of establishing causality.

Until biomarkers can provide the kind of specificity between contaminant and response that exists between antigen and antibody, what is required is a set of **operational criteria** for causality that are straightforward to satisfy, and can be likened to Koch's Postulates (rules proposed for identifying the causal microorganisms of diseases). The problem was just as intractible then as that of establishing links between pollutants and their effects now. Even the relatively simple example of tributyl tin, which typically occurs in otherwise unpolluted estuaries, took over a decade to establish causality beyond doubt. These operational criteria for causality should be directed to quickly establishing a high probability of causality, using techniques that are already available to the regulatory authorities. In this way the questions of the greatest concern to those who achieved its incorporation in the Ministerial Declaration (1987), and those worried by the time taken to establish causality in recent examples such as TBT, would be addressed.

This is not the right context in which to propose operational criteria for establishing causality, as it would be the general acceptance of a set of criteria, rather than their selection that would make the idea operable. Nevertheless, the list might include some of the following:

1. Spatio-temporal correlation of contaminants in water and/or sediment and its putative deleterious biological effect. While correlation can never be diagnostic, causal agents must - at least to some extent- share a similar distribution in space and time as their effects. Greatest problems occur where exposure and its effect are widely separated in time, so that movement and migration of organisms confounds distributional data. For mobile species rapid responses to toxic contaminants are essential.

2. The occurrance of the contaminant in tissues of the organism supposedly effected, causality would be assumed if tissue levels exceeded some threhold concentration known to be capable of inducing a deleterious biological effect. The use of such data circumvents the whole question of bioavailability; toxic biological effects result from contaminants within the organism.

3. Causality would be assumed where the occurrence of tissue, water or sediment concentrations exceed those known to be able to induce a deleterious biological effect.

4. Indices ("biomarkers") which to a greater or lesser extent identify the cause(s). (eg MFO induction, metallothionein induction, imposex on dog whelks)

(Any of these criteria could be made more specific by statistically specifying the degree of correlation, or the margin of overlap of water, sediment or tissue concentration and toxicological thresholds.)

6. ENVIRONMENTAL ECONOMICS

The primary justification for protection of the marine environment used to be fish, shellfisheries and other economically important species. In recent years, the conservation of marine communities has become an end in itself, but the cost of pollution control measures is often so great that there are not adequate funds and the implementation of environmental legislation has often been deferred and delayed. There are few examples where spatial definition and frequency of monitoring are are adequate to ensure environmental protection. The cost of curating the marine environment was far greater than the value assigned to it by society and governments.

In the United Sates and elsewhere there is a move to harness market forces to pay for environmental protection (Wirth and Heinz, 1988), which is now being built upon in the UK (Pearce et al., 1989). We should value the capacity of the marine environment to assimilate wastes as a resource that has an economic worth to those who utilise it.

Any capacity of receiving waters to assimilate wastes and effluents is in part due to biological processes that contribute to it (Stebbing and Harris, 1988). Toxic effects will result if the capacity to assimilate is overloaded, reducing environmental capacity and destabilising the system through postive feedback. Environmental capacity should therefore be conserved by protecting biota that contribute to it.

While there exist a growing body of legislative controls and constraints, it is inevitable that any resource freely available will become overexploited. Examples of the over-exploitation of natural resources for which there were inadequate controls abound. Overfishing is a familiar example to us all. It is essential therefore to limit the extent of usage by imposing an environmental charge, or tax on effluent inputs, together with an overall quota of usage to prevent overloading of the environmental capacity. The use of the resource by industry and society has a value which can be expressed in terms of the cost of alternative means of disposing of the waste.

Overexploitation could be prevented by imposing a charge on effluents and wastes [illegible] released in the marine environment, with the total amount less than co[illegible] "unacceptable" biological impact. This could be operated as an open market [illegible] of environmental capacity could be purchased by environmental and conser[illegible] which they could then freeze, so providing greater environmental protecti[illegible] feel the level of biological impact deemed "acceptable" was too great.

Any charge for the use of the environmental capacity should be scaled with a cost per toxic quantum of effluent, rather than
chemical terms alone, so that environmental use can be scaled in terms of the biological effect that it is aimed to minimise. This would emphasise the fact that the primary concern is to maintain the biological integrity of the environment and is not merely the occurrence of chemical contamination. It would also be cheaper to monitor and provide an incentive to the discharger to develop cleaner technology and decrease the toxicity of the effluent, should they wish to discharge greater volumes. The introduction of toxicological consent setting by the UK National Rivers Authority reflects similar thinking.

Such an approach would provide an income commensurate with the task of maintaining the environment as a valued resource. Funds that derived from imposing charges for the use of the environmental capacity would be directed to those with responsibility for managing and monitoring the environment, providing a level of resourcing necessary to ensure monitoring with a scale and frequency necessary for adequate protection of the environmental capacity as a resource. While this may be seen by some as a license to pollute, it is inevitable that any natural resource freely available is bound to become overexploited, unless it is tied into the economic system that exploits it and assigns to it a realistic value which provides for its protection. Thus environmental capacity is a concept whose worth is not merely a framework for existing control procedures, but linked to the economic system, provides the best hope for affordable environmental protection in the long term.

7. CONCLUSIONS

1. "Environmental capacity" is a scientifically sound concept that describes the ability of the environment to assimilate wastes and effluents. Application of the concept sometimes fails in operation because available knowledge is not adequate, and the assumptions made in calculating environmental capacity are too great. It is important therefore to improve the kinds of understanding and data necessary to estimate environmental capacity more accurately.

2. In the absence of a concise definition the "precautionary principle" is assumed to mean that greater caution is needed in utilising the environment to dispose of wastes, due in part to the difficulty in establishing proof of causality. The principle incorporates the requirement that any material should be demonstrably safe or harmless before release into the environment. The transfer of the burden of proof and the requirement to demonstrate harmlessness are impractical, although there is no doubt that greater caution is essential in the use of the environmental capacity.

3. There is a requirement for an agreed set of "Operational criteria for establishing causality" that are easier and quicker to establish, with existing methods, to an adequate degree of probability than scientific proof.

4. Greater efforts should be made to speed the development of techniques, that can provide the means of linking contaminants to their biological effects in the environment. An important development are those techniques termed "biomarkers" where the biological response itself identifies its cause(s).

5. Environmental capacity is a resource, which is its capacity to degrade, sequester or recycle wastes and contaminants, but overexploitation of the resource can only be prevented if its use is more closely regulated in relation to scale of the available resource. Usage of the resource must fall short of an "unacceptable" biological impact.

6. Effective management of environmental capacity depends on its acceptance as an economic resource which should be paid for by those who use it. Overexploitation would be prevented by imposing a charge per toxic quantum of waste , with the total amount of chargeable toxic quanta available that in total is less than could cause an "unacceptable" biological impact.

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