Communication

A critique of assimilative capacity

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As any science or area of technical expertise develops, there is an increasing need for a technical language to simplify communication between exponents and to enable ready discussion of newly discovered phenomena. For the developed language to be most useful, terms used should have some degree of precision. Exponents of the technology should agree on the meaning of the new terms, and the terms should have some clear use or task. They should describe or specify actual phenomena or relations. There has been an unfortunate trend in technology to deliberately introduce new terms to "mystify" a particular branch of technology, and make it seem more complex and more sophisticated than it is. This trend has become apparent recently in applied aquatic science.

One of the terms that is commonly occurring in the literature of applied water science is *assimilative capacity*. This term, which seems to have come into use in the mid-sixties, suffers from two major faults. First, it is used by two groups of technologists working in related areas to mean different things. Second, in both cases the term is inappropriate or meaningless.

Assimilative capacity has never been strictly defined. Different authors give varying definitions, or none at all. The strict definition of assimilation most appropriate to the term as used in water science is "to convert into a substance of its own nature; to absorb into the system; incorporate."[1] The implication, where waste discharges to water are involved, is that the waste becomes incorporated into the receiving system without alteration of the receiving system. Where definitions of assimilative capacity are provided in the literature, they are expressed in terms of the ability of receiving waters to absorb waste discharges without suffering deleterious ecological effects.[2,3] Such a definition is both extremely vague and extremely subjective.

It is not clear, for example, what is meant by an "ecological effect." Does this mean the death of individual organisms, the elimination of food chains, or a change in energy flow patterns to both? Nor is it clear whether a distinction between deleterious and beneficial or nondeleterious ecological effects is intended, and if so, the nature of the difference.

Assimilative capacity and water chemistry. Although the definitions provided in the literature are extremely general, wastewater engineers and chemists frequently use "assimilative capacity" in a far narrower context. For example, the term is often used to specify the volume of a waste that may be discharged into a receiving water without lowering the ambient dissolved oxygen (DO) concentration below a specified level. Novotny and Krenkel[3] defined waste assimilative capacity as "the amount of waste material that may be discharged into a receiving water without causing deleterious ecological effects," but the model they proposed to determine this capacity considered only oxygen. Busch[4] also defined assimilative capacity broadly, but applied it purely to DO. Other authors have also used the term in this narrow sense[5–9] without defining it.

Some workers have used assimilative capacity more broadly as the ability of a receiving water to absorb wastes without exceeding any of a set of chemical or microbiological criteria. Bauer *et al.*,[10] for example, considered DO non-ionized ammonia, nitrogen, fecal coliform bacteria, total nitrogen, and nitrate nitrogen in developing a predictive model of assimilative capacity of the Yampa River.

It is clear that the use of the term "assimilative capacity" is inappropriate and unsatisfactory in the cases above, although there is apparently general agreement on the concept of assimilative capacity judging from the agreement between the definitions provided in the literature in those cases where definitions are provided at all. However, authors are not using the term according to their own definitions and, even more critically, different authors are using the term in different ways. The solution is simple. The term "assimilative capacity" should be abandoned in cases such as those cited above.

Some alternative terms are already in use in the literature. Where DO concentrations are the sole object of the investigation, the terms "re-aeration" and "re-aeration capacity" are more explicit and accurate. When a number of chemical or microbiological parameters are being investigated, the actual phenomenon being investigated is the waste treatment capacity of the stream. That is, the waste discharger is using a section of stream as a part, or in some cases, the entire waste treatment program. The term "waste treatment capacity" makes it clear that one of the beneficial uses of the segment of stream is waste treatment,[11] and therefore makes this fact less likely to be overlooked in cost-benefit analyses. For this reason, the term may at times be unpalatable to politicians and others who profess to believe in the "free lunch" concept whenever convenient. Despite this, the term is more accurate and honest, and therefore preferable.

Assimilative capacity and ecology. Before discussing the biological viewpoint of assimilative capacity, it is worthwhile to review briefly the accepted wisdom of ecology. Together with the rest of science, ecology is fundamentally deterministic in outlook. Ecologists accept that cause and effect relationships, albeit complex, occur within ecosystems, and that the structure and functioning of ecosystems are determined in part by the abiotic materials contained within, entering, and leaving the ecosystem.[12] In aquatic systems, allochthonous inputs may include various natural and man-made materials. A part of the ecological paradigm is that such materials have an effect on the biological community whether the input to the community, for example, is smaller than a leaf or larger than a tree.[13] The effects generated as a result of these inputs may also be large or small, depending on the total volume of material entering the system, the rate at which it enters, and the way in which it interacts with the preexisting system. The result is a changed system. This is part of the reason that ecosystems must be considered as continually changing dynamic systems—a point that Cairns[14] and others [15,12] have rightly emphasized.

Just as natural materials entering a system necessarily change it, so do man-made materials. Once again the effects may be large or small, depending both on the amount of material and the nature of its interaction with the system. For example, the addition of 20 l of raw wastewater to a stream will have far less impact than the addition of the same volume of insecticide.

The biotic community within a stream or any other ecological system does not have a preexisting capacity to absorb any allochthonous input. The community present at any given time is, in part, the product of previous inputs. A new input, such as a waste discharge, will cause the community to change until a biotic community capable of utilizing or, in the case of toxic materials, resisting the discharged material is produced. The critical point is that the biological community will not remain the same—thus there is no assimilative capacity. There could only be a preexisting capacity if the community could in some way anticipate the discharge, as Wohrmann[16] has previously noted.

As one of the major protagonists for the assimilative capacity concept amongst ecologists, Cairns has defined assimilative capacity in a similar fashion to the definitions previously cited, namely, the ability of an aquatic system to assimilate a substance without degrading or damaging its ecological integrity. He defines ecological integrity[14] as the maintenance of structure and function characteristic of a particular locale or deemed satisfactory to society. The difficulty of these definitions is their dependence on subjective value judgments. The introduction of the term "ecological integrity" into the definition of assimilative capacity further compounds the confusion.

The concept of ecological integrity is itself vague, open to disparate interpretations and not yet practically useful.[17] Cairns[14] suggests a number of potentially fruitful criteria for quantifying integrity in aquatic systems. One, which I shall use to illustrate my argument, is "species diversity," although the argument is equally applicable to the others he suggests. The principle on which the use of diversity indexes is based that as the ecological integrity of an ecosystem is damaged, the diversity of species within it will decrease. The problem previously encountered, of how much change in diversity constitutes damage to ecological integrity, is still unresolved. An additional problem with diversity (although not with some of the alternative criteria Cairns suggests) is the plethora of techniques for evaluating diversity that have been advocated by various authors,[18] and may give contradictory results.[19]

Additionally, streams with low natural diversity could experience a waste discharge or other human modification that could actually increase the biological diversity present. Under Cairns'[14] definition of integrity, this increase would presumably be considered damaging to it. Others may argue that, in fact, an increase in diversity improved integrity. It is necessary to clarify whether any change in diversity, or only a decrease, is considered damaging to the integrity. If any detectable change is considered damaging, then the means of detection must be specified and, presumably, as ecological methods become more sensitive, effluent quality would be required to improve.

Westman[20] contrasted the technological approach to water quality, which is not based on assimilative capacity, with an alternative that he designated the ecological approach, which is based on assimilative capacity.

He argues that a necessary corollory of the ecological approach to water pollution control is a "no discharge" philosophy. This, he suggested, is also a more pragmatic approach, because our present predictive ability is far too poor to allow accurate extrapolation from discharge data to ambient water quality. Yet this predictive ability is demanded by both the assimilative capacity approach and the ecological approach, if discharge is to be permitted while maintaining a predetermined level of water quality.

Cairns[21] also argues that the critics of assimilative capacity, by insisting that the introduction of any material into a system causes a change that would not otherwise have occurred, imply that such a change is necessarily deleterious and consequently must support a "no discharge" philosophy. He suggests that such a philosophy is impractical, both economically and politically. Although the ecological approach to water quality has often been linked to a "no discharge" philosophy, there is no logical necessity for such a linkage.

Cairns[21] asks, "Is a microgram of glycolic acid placed into an ecosystem by an algal population less of a threat to the biological integrity of an ecosystem than the same amount discharged from an industrial or municipal waste pipe?" and goes on to note that, "If you believe that there are some ecosystems into which this amount of . . . glycolic acid might be introduced without damaging the structural or functional integrity of the ecosystem, then you cannot deny the existence of assimilative capacity. . ." However, Cairns misses the point. The glycolic acid, from whatever the source, will change the structure and functioning of the community into which it enters. The change may well be extremely slight—a matter of a few bacteria surviving where they would otherwise not have, or dying when they would have survived—but because the community will respond, the stream cannot be said to have had an assimilative capacity.

Conclusion. As I have pointed out, ecologists generally believe that, when a new input into a biological system occurs, as it is when a waste is discharged, the system will respond with changes in structure or function. These changes may be as slight as a change in physiological functioning of a single organism, or as drastic as the complete elimination of the larger life forms. The difficulty lies in deciding the degree of change that constitutes "damage."

One can quite reasonably argue that a microgram of glycolic acid discharged into a stream did cause a change, but that the change was insignificant and therefore could not reasonably be described as deleterious. In the case of a discharge that increased diversity, it could also be reasonably argued that the change was not deleterious, and the same for discharges that led to increased numbers of a desired species.

Even if it were accepted that any discharge would be deleterious, this does not necessarily lead to a zero discharge philosophy, as Cairns and Westman argue. The argument then revolves around acceptability of the deleterious change. The introduction of food rationing during periods of war is a deleterious change the population generally finds acceptable. The critical shortcoming in all the definitions of assimilative capacity is that they all necessitate a value judgment, a decision on what is acceptable to the community and what is not.

The pseudotechnical language involved in terms like assimilative capacity, in fact, disguises a value judgment as a technical decision. The assimilative capacity concept proposed by Cairns allows the biologist or aquatic scientist to decide the acceptable degree of change in the ecological community of a receiving water, by pretending that assimilative capacity is an absolute measurable property of a receiving water, and we need only overcome a few technical difficulties before we can use it.

Any discharge will cause a change in the biological community of the receiving water, and it is up to aquatic scientists to develop effective means to measure and hopefully predict those changes. It is not the job of scientists to decide how much change society will accept, although scientists should have a voice as members of society—and possibly a louder voice than most, because those working with aquatic communities probably have a greater appreciation of their value than many other members of the community. Those directly answerable to society, the politicians, are employed to make value judgments; we should not do their jobs for them.

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