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PROBLEMS IN IMPLEMENTATION OF US EPA WATER QUALITY CRITERIA INTO STATE WATER QUALITY STANDARDS

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ABSTRACT

PL 92-500, the 1972 Amendments to the Water Pollution Control Act, requires that the US EPA develop water quality criteria which can serve as a basis for development of state water quality standards. At this time many states are attempting to adopt the numeric values of the US EPA July 1976 Red Book criteria as their water quality standards. This approach is not technically valid and can result in expenditure of unnecessarily large amounts of money in the name of water pollution control. The basic problem with this approach is that the US EPA criteria are generally based on an assumption of the worst case conditions of 100% available forms of contaminants and chronic exposure of organisms to the contaminants. While this approach is administratively simple and generally protective of aquatic systems, it will not result in the best use of the financial and energy resources for water pollution control. This paper discusses some of the problems of trying to implement the US EPA Red Book criteria into state water quality standards.

In order to be legally enforceable, a standard must be analytically measurable. There are several examples of contaminants which cannot be analytically measured at the criteria levels. Standards must also take into account the fact that contaminants exist in aquatic systems in a variety of forms only some of which are available to affect aquatic organisms. Further, since physical and chemical contaminants typically affect beneficial uses of water as a function of not only concentration but also duration of exposure, water quality standard violation should not be

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assessed based on a single concentration value or some statistical average value, but rather on the concentration of available forms - duration of exposure coupling. Water quality monitoring programs must be designed to take this into account. Since chemical analytical procedures rarely distinguish between available and unavailable forms of contaminants, increasing use will have to be made of aquatic organism bioassays in assessing the potential for water quality impairment to occur as a result of contaminant discharges.

The failure of the US EPA to provide the kinds of information needed by state and local pollution control agencies to properly implement their water quality criteria into technically valid water quality standards is causing widespread concern and consternation in the water pollution control field about the ability of this agency to properly implement the provisions of PL 92-500.

INTRODUCTION

In accord with the provisions of PL 92-500, the 1972 Amendments to the Federal Water Pollution Control Act, the US EPA must develop water quality criteria which are to represent the current state of knowledge on the impact of physical, chemical, and biological contaminants on water quality. The US EPA has, by necessity, adopted "worst case" criteria (US EPA, 1976 Red Book); that is, these criteria are generally levels of contaminants in 100% available forms which are, based on current knowledge, safe for sensitive organisms to be exposed to for their entire lifetimes or during critical stages of their lives. While in the Foreword to the US EPA Red Book R. Train, then US EPA Administrator, stated:

> "Guidelines to implement the consideration of criteria present in this volume in the development of water quality standards, and in other water-related programs of this Agency, are being developed and will be available for use by the states, other agencies, and interested parties in the near future."

to date, some four years after the Red Book was released, the US EPA has still not provided appropriate guidance in this regard. According to current US EPA policy, state water quality standards for the total concentration of a contaminant in a water must be at least as stringent as the worst case US EPA water quality criteria or the state must demonstrate why a more lenient standard should be accepted. Many states, which are currently in the process of developing or revising their water quality standards, are adopting the numeric values of the US EPA July 1976 criteria as their water quality standards.

PL 92-500 also set as a national goal zero pollutant discharge. While not specified in the Act, the US EPA water quality criteria will certainly serve as a basis for distinguishing between discharge of a "pollutant" and discharge of a "contaminant." A "contaminant" is any material added to a water. A "contaminant" becomes a "pollutant" when its critical ("no impact") concentration - duration of exposure coupling is exceeded, causing an adverse impact.

When PL 92-500 was passed, there were many who questioned the economic and technical feasibility of achieving zero pollutant discharge and using numeric values of the worst case water quality criteria as state water quality standards. However, as late as 1977 when PL 92-500 was amended, the mood of the U.S. and, most importantly, its national, elected representatives, has been such that the basic philosophy of the Act remained essentially unchanged. Today, as the date for achieving zero pollutant discharge draws near, there are many more who question not only the desirability of achieving this goal because of its economic and social ramifications but also, more importantly, the desirability of adopting the US EPA water quality criteria of July 1976 as state water quality standards to in turn serve as a basis for waste load allocations in water quality limited waterbodies.

The General Accounting Office (GAO) has recently reviewed, in a report entitled "Many Water Quality Standard Violations May Not Be Significant Enough to Justify Costly Preventive Actions" (GAO, 1980), the potential cost-effectiveness of advanced wastewater treatment (AWT) as a means of further reducing contaminant concentrations in domestic wastewater. It has recommended, according to a report entitled, "GAO Questions $10 billion cost for Advanced Wastewater Treatment" (Air/Water Pollution Report, 1980), that

> "Congress should declare a moratorium on advanced wastewater treatment (AWT) projects by withholding funding for treatment beyond secondary until the Environmental Protection Agency 'can clearly show what ecological, social, and public health benefits are being realized by the various levels' of AWT . . ."

PROBLEM IN USING WORST CASE CRITERIA AS WATER QUALITY STANDARDS

The basic problem with using the numeric values of the US EPA July 1976 water quality criteria as the legally enforceable water quality standards is that, for the most part, natural water systems do not represent worst case situations. As discussed by Lee et al. (1980a), there are a number of characteristics of chemicals as well as natural waters which reduce the potential impact of a chemical on water quality (fisheries, drinking water supply, recreational utility, aesthetic quality, etc.)

CONTAMINANT AVAILABILITY

Many chemical contaminants exist in aquatic systems in a wide variety of forms, only some of which may be available to cause an adverse effect on beneficial uses of the water. While the US EPA water quality criteria generally try to take into account the impacts on toxicity of such parameters as hardness and alkalinity, they disregard the more significant impacts of a variety of chemical reactions on toxicity of chemical contaminants. One of the most important reactions which renders many potentially hazardous chemicals unavailable (non-toxic) or less available to aquatic life is sorption. (It should be noted that sorption is frequently mislabeled as "complexation" by various investigators in explaining the change in behavior of a contaminant, such as a heavy metal, when placed in natural water systems; this change is, however, more likely due to sorption on colloidal materials.) Several years ago, the authors conducted a major study on the significance of dredged sediment-associated contaminants in affecting water quality during dredging and disposal operations (Jones and Lee, 1978; Lee et al. 1978; Jones et al. 1980). They found, as expected, that even though sediments often contain very high concentrations of a wide variety of chemical contaminants, they are not typically released in significant quantities to overlying waters. Even when dredged sediment are disposed of in open water, rarely would sufficient amounts of contaminants be released to cause mortality to pelagic organisms of the disposal area.

It is not only sorption on sediments which renders contaminants unavailable or less available, but also sorption on other materials as well. As discussed by Lee (1975), iron and aluminum hydrous oxides play extremely important roles in controlling the availability of many chemical contaminants in aquatic systems. Ferric hydroxide tends to form amorphous colloidal particles (floc) which effectively sorb many contaminants of concern. Contaminants sorbed on such material have markedly different bioavailabilities than contaminant forms conventionally used in laboratory toxicity and bioavailability testing.

Complexation also plays a role in affecting the toxicity of some contaminants. Soluble forms of contaminants, especially heavy metals, can be complexed, rendering them unavailable or less available to affect water quality. Complexation, however, as discussed by Sanchez and Lee (1973) can also act to make certain contaminants more available by causing their desorption from particulate matter and creating soluble complexes which are more available. Other potentially important reactions affecting contaminant availability include oxidation-reduction, photolysis, hydrolysis, precipitation, acid-base, gas transfer, and biotransformation. The significance of the thermodynamics and kinetics of these reactions in affecting contaminant availability have been discussed by Lee et al. (1980a).

An example of the changes in availability of contaminants as a function of characteristics of the water, was provided by the work of Morrison and Post at Colorado State University (Morrison et al. 1979). They conducted a series of laboratory bioassays using waters from various reaches of the Poudre River (Colorado) spiked with copper, cadmium, silver, and ammonia to determine 96 hour LC_{50} values for trout and fathead minnows. The almost pristine water of the Poudre River flows from the Colorado Rockies into the plains of the Front Range of Colorado. During much of the year, within a short distance of the mountains, the water from the Poudre is diverted for irrigational purposes to the point that at some times of the year, this diversion depletes the river of water. Except during flood-flow periods, by the time the water passes through Fort Collins, a distance of about 20 river miles, the pristine water has essentially been completely replaced by domestic wastewaters which have been discharged to the river, irrigation return flows, and shallow groundwater seepage arising from irrigation. This markedly changes the chemical characteristics of this water. Morrison et al. (1979) found that the 96 hour LC_{50} values of the chemicals tested in samples of Poudre River water as it leaves the mountains in a pristine state, closely match those reported in the Red Book for many of the contaminants tested and the organisms used. The toxicities of the same chemicals to the same types of organisms in water taken from the Poudre River downstream of the City of Fort Collins were an order of magnitude less. While the reason for this decrease in toxicity is not clear, a substantial part of the difference appears to be due to differences in alkalinity and hardness of the river water. It is possible that it also relates to the increased presence of organic compounds and other particulate matter which tend to sorb and complex heavy metals.

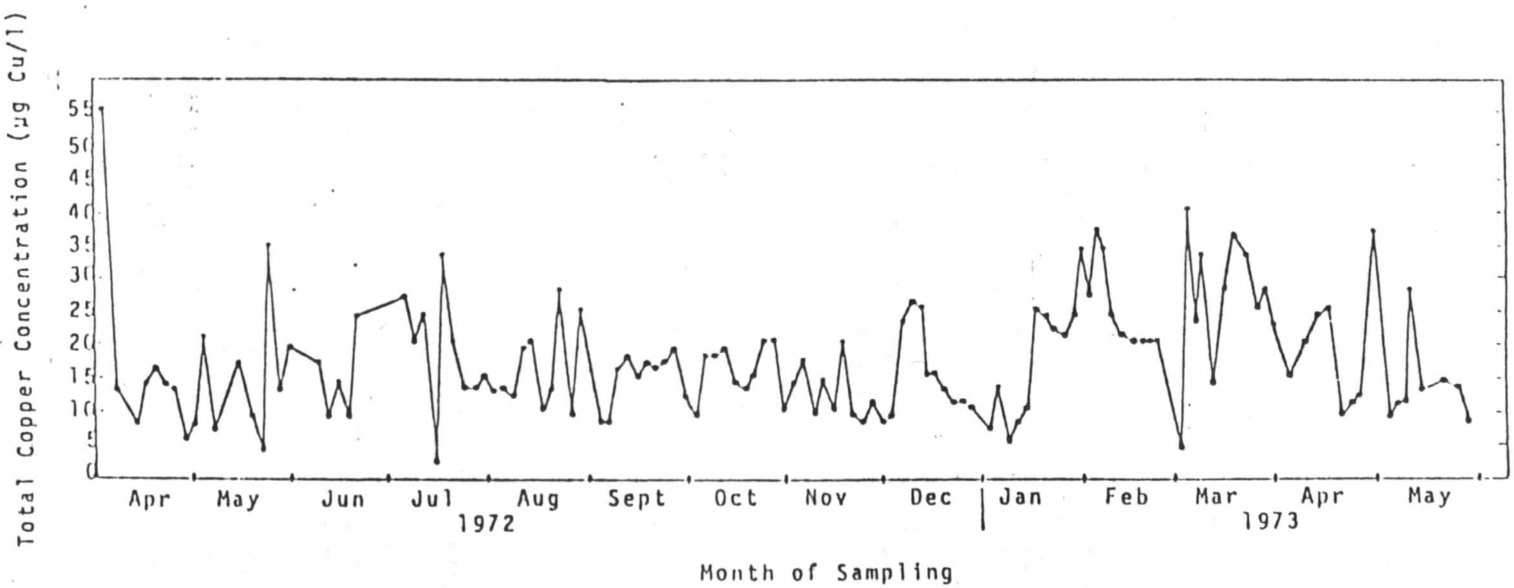
While, for many waters, measurement of the "soluble" fraction of a contaminant generally gives a better estimate of the available fraction than measurement of the total concentration, it can result in either overestimation or underestimation of the potential toxicity or bioaccumulation of a contaminant. For example, as discussed previously, ferric hydroxide colloidal material is an efficient scavenger of many potentially hazardous contaminants. However, some of these particles are small enough to pass through the standard 0.45 μ pore size filter used for separation of "soluble" and "insoluble" components, causing some of the sorbed colloidal material to be measured as soluble. At this time there is no simple, chemical test that can be used to distinguish between available and unavailable forms of contaminants in aquatic systems. As discussed by Lee et al. (1980a,b), the only way to properly distinguish between these groups is through the use of aquatic organism bioassay test procedures.

VARIABLE CONCENTRATIONS

The second reason that the US EPA water quality criteria are difficult to use directly as water quality standards is the fact that these criteria, because they represent safe concentrations under worst case conditions, assume that aquatic organisms receive chronic exposure to the level of contaminant found at a particular sampling time. Usually chronic exposure means lifetime exposure or exposure for significant parts of important life stages of aquatic organisms. As discussed by Lee et al. (1980a), it is rare that the concentrations of contaminants associated with any discharge are constant. Typically these concentrations are continuously varying by orders of magnitude over a 24-hour cycle. Further, the waters into which they are discharged, particularly streams and rivers, have varying flows depending on season, time of day, degree of regulation, etc. The net result is that the concentrations of many contaminants of greatest concern are highly variable in many aquatic systems. Lee and Jones (1979b) conducted an evaluation of the water quality-related data collected on Lake Ontario and its U.S. tributaries during the International Field Year for the Great Lakes (IFYGL). They found that water samples collected every three days from the mouth of the Genesee River over a one-year period had concentrations of total copper which varied from about 2 to 55 µg/l, as shown in Figure 1. Since available copper is typically toxic to some aquatic organisms in this range, if the standard is established in the 15 to 25 µg/l range, there would be frequent excursions above the standard for short periods of time. As discussed in a subsequent section, this may or may not have an adverse impact on aquatic organisms.

In a study recently completed by Lee et al. (1980c) in which chlorine concentrations were measured every several hours over a four-day period on water samples collected from the Arkansas River at the Pueblo, CO, sewage treatment plant discharge, it was found that chlorine concentrations ranged from 0.02 to 0.26 mg/l Cl_2. During the same study period, the daily water temperature fluctuated by 10 C °. Based on the experience of the authors, these kinds of variations are not uncommon in aquatic systems. Studies conducted by Kodak of Colorado on the toxicity of ammonia to adult fathead minnows (Morrison et al. 1979) has shown that these organisms could be exposed to 0.1 mg/l un-ionized ammonia for a period of 28 days without experiencing any deaths. Further, when they were exposed to ammonia concentrations of 0.3 mg/l un-ionized ammonia for several days in sequence and then to the 0.1 mg/l un-ionized ammonia base level, there were no deaths of organisms in the 28-day test period. Exposure of fathead minnows to 0.3 mg/l un-ionized ammonia for on the order of one week will result in organism mortality. Exposure to 0.4 mg/l un-ionized ammonia will result in fathead minnow

Figure 1. Total Copper Concentrations at the Genesee River Mouth (Lake Ontario)



After Lee and Jones (1979b).

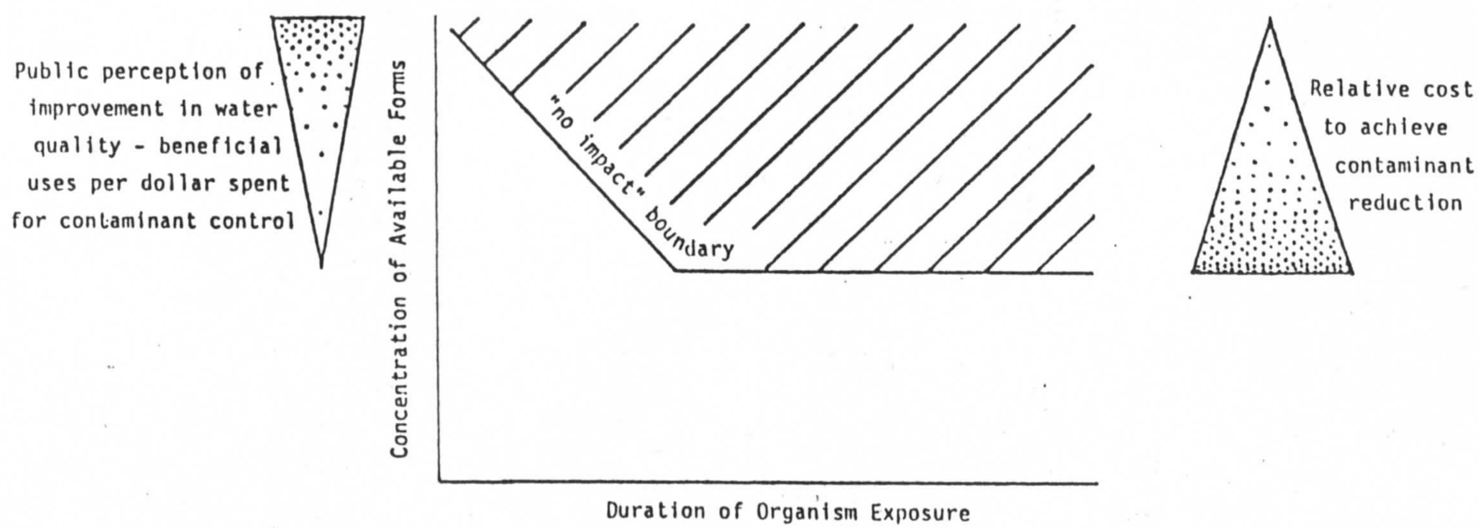
mortality in several days. (It should be noted that the endpoint in these bioassays was death; there may be some chronic impacts on adult fathead minnows or other adverse effects on other life stages of fathead minnows at these levels.)

Under conditions where the concentrations of a contaminant downstream of a point source are typically at or near the Red Book criterion value, there could be excursions of concentrations to levels an order of magnitude greater than the Red Book value. If, as is the typical case in many states, exceeding the standard in a single sample constitutes a water quality standard violation, it is possible that a water quality standard is exceeded without there being any adverse impacts on water quality. To properly implement water quality criteria into water quality standards, consideration must be given to the fact that concentrations of contaminants in available forms can greatly exceed, for some period of time, the criterion value without adverse effect on the beneficial uses of the water. These situations create considerable misunderstanding on the part of many water pollution control practitioners, governmental agencies, industrial representatives, and others. It is difficult for persons with limited knowledge of aquatic chemistry and toxicology to understand that there are times when the concentrations of certain contaminants in rivers, streams, lakes, or estuaries are considerably above the Red Book, worst case criteria value without there being a significant hazard to aquatic life. In situations such as these, it is not unusual for electroshocking or other fish population evaluation techniques to show that there are appreciable concentrations of organisms present in the region with the apparently excessive concentrations of chemical contaminants. This should result in public opposition to attempts to impose Red Book criteria as single, fixed numeric standards which, if exceeded in any sample of water, signals a violation of the state pollution control regulation.

CONCENTRATION - DURATION OF EXPOSURE RELATIONSHIPS

The fact that contaminant concentrations in a given aquatic system are often highly variable and can fluctuate considerably above and below chronic safe levels necessitates the consideration not only of concentrations of available forms of contaminants relative to chronic safe levels in assessing hazard and hence in developing standards, but also of the length of time that organisms are exposed to potentially hazardous (i.e., greater than chronic safe) levels. As discussed by the authors (Lee et al. 1980a,b) it is well known that organisms can be exposed to concentrations of available forms of contaminants substantially higher than the US EPA Red Book criteria without there being an adverse effect on beneficial uses of the water. Figure 2 illustrates this relationship showing that for shorter durations of organism exposure, "no impact" concentrations are higher than those at the chronic exposure plateau.

Figure 2. Relationships among Potential Impact of Contaminants on Water Quality - Beneficial Uses of the Water, Relative Costs to Achieve Various Degrees of Water Quality Improvement, and Perceptibility of Various Degrees of Improvement in Water Quality to the Public.



An example of the importance of considering the duration of exposure in assessing impact of contaminants is provided by chlorine. The chloramines that are present in domestic wastewaters as a result of chlorination for disinfection purposes will, at concentrations of approximately 0.5 mg/l, kill certain types of fish within a few hours. The 96 hour LC_{50} for the chloramines typically present in domestic wastewater effluent after chlorination is on the order of 0.1 mg/l, while the chronic - lifetime exposure safe concentration is on the order of 0.005 mg/l. There are two orders of magnitude difference between the level which will cause acute lethality in aquatic organisms in a few hours and the chronic safe concentration. A similar situation exists for ammonia. The chronic safe concentration for warm water fish is generally recognized to be on the order of 0.05 mg/l un-ionized ammonia, while fish of the same type can spend months in waters having concentrations on the order of 0.1 to 0.2 mg/l un-ionized ammonia.

As discussed in the American Fisheries Society critique of the Red Book ammonia criterion (Willingham et al. 1979), ammonia and many other contaminants at concentrations between the acute lethal concentration (i.e., that which will kill the organisms in four days) and the chronic safe value (i.e., Red Book value), affect organism characteristics such as weight, growth rate, susceptibility to disease, etc. While it is generally believed that the majority of the public would strongly support the kind of control programs which would prevent the death of fish, it still remains to be seen whether or not the public in general wishes to pay the enormous costs, either through their taxes or increased price of goods, for the control of contaminants to the point of eliminating the potential of chronic toxicity manifested in decreased rates of growth, slightly less healthy fish, a somewhat impaired reproduction rate, etc. While there may be considerable sympathy for control of contaminants to prevent acute lethal toxicity, it is highly doubtful that the public as a whole will pay for contaminant control programs to provide the ultimate, based on amount of suitable habitat, in fisheries for a particular waterbody. It is important that the public be informed as to the potential benefits that will be derived from controlling contaminants to the degree necessary to achieve Red Book criteria.

AVOIDANCE

Another factor that causes considerable confusion in assessing the actual significance of a particular point source discharge of a contaminant as a cause of impairment of beneficial uses of water, and that renders inappropriate the blanket comparison of a concentration of a contaminant in a water with worst case numeric standards, is the avoidance reaction of fish and other mobile aquatic organisms. For example, in the case of chlorine, it is well known that fish will avoid high concentrations of chlorine, given the opportunity to do so. While avoidance is well recognized as a phenomenon by which fish can naturally minimize their exposure to adverse concentrations of some chemicals, there is also an attraction of fish to some point source discharges, for example, some with elevated temperatures. This could cause an increased exposure to some contaminants over that which would normally occur. There is insufficient information available at this time to know whether during winter conditions a chlorinated domestic wastewater effluent would, because of its elevated temperatures, attract the fish more, or because of high chlorine concentrations, repel fish. The information base is grossly inadequate to make any conclusions as to whether avoidance or attraction to a particular effluent will be the dominant behavioral pattern of a certain type of fish in a certain location.

ACCLIMATIZATION

Certain aquatic organisms can become acclimatized to elevated levels of available forms of certain contaminants if they have been exposed to them previously or continuously. Such organisms can tolerate without any apparent, significant harm, relatively higher concentrations of the contaminant than can the same kind of organisms suddenly introduced into the higher concentration waters. This is another factor that should be considered in assessing the hazard associated with a contaminant as it is one which tends to reduce the potential for impairment of beneficial uses of a water by a chemical contaminant.

ANALYTICAL CONSIDERATIONS

In order for water quality standards to be enforceable, it must be possible to collect an appropriate water sample and to reliably measure the contaminant in a water sample at and below the level of the standard. Some of the US EPA Red Book criteria are below reliable analytical detection limits. For example, sulfide is toxic to fish eggs at a few µg/l. Not only is it extremely difficult to collect a proper water sample from the sediment/water interface where many types of fish eggs would be found, but also it is difficult to reliably measure sulfide in this water at these levels. Similarly, while PCBs can be measured down to 2 to 3 ng/l in water under optimum conditions, the PCB criterion is 1 ng/l. Since for PCBs, the concern is their concentrations in edible fish flesh, it has been recommended by the American Fisheries Society PCB criterion review panel (Veith <u>et al.</u>, 1979) that PCB standards be for fish flesh content rather than for water. This can be readily accomplished because the Food & Drug Administration has PCB limits for edible fish flesh and PCBs can be readily measured at and below the FDA limits. The same approach should be used for other contaminants for which the concern is bioconcentration-bioaccumulation. Lee and Jones (1979a) discuss considerations that must be made in interpreting chemical water quality data.

As indicated previously, the US EPA-Washington has been delinquent in providing appropriate guidance for implementation of the Red Book criteria into state water quality standards. If it is the intent of the US EPA-Washington to have the states use the numeric, worst case Red Book criteria values directly as water quality standards, then it has been grossly negligent in insuring that suitable analytical techniques are available for measuring contaminants at and below criteria levels. In the early 1970s it was called to the attention of the US EPA-Washington by Lee et al. (1974) and others that a number of the then proposed criteria would be essentially worthless as standards unless substantial funding were made available for development of suitable analytical procedures. Since that time, the US EPA has devoted inadequate attention (funding) to this area with the result that states are having great difficulties in developing appropriate, enforceable standards. Those responsible for criteria promulgation have taken the attitude that criteria promulgation should not be dependent upon the availability of analytical procedures, and frequently express the view that analytical procedure development is the responsibility of other groups within the US EPA. It is clear that if the Red Book criteria are to be used as state water quality standards, a substantial effort should be undertaken in the immediate future to develop the necessary analytical procedures.

APPROACH FOR DEVELOPMENT OF WATER QUALITY STANDARDS

As discussed in the Introduction, PL 92-500 and its 1977 amendment set forth a number of target dates for attainment of various degrees of pollution and contaminant control in US waters. The most immediate goal is that of attaining swimmable, fishable waters in the US by 1983. In this regard, there seems to be some confusion as to what is meant by "fishable" water. Environmental activist groups, the federal and some regional EPA groups, as well as some state pollution control agencies, have taken the attitude that "fishable" means the ultimate in fisheries potential. There is even question about what the "ultimate" in fisheries means; it could mean large populations of desirable game fish or a more "balanced" fishery containing a certain diversity of species containing both desirable and less desirable fish. In either event, it does imply that the numbers and types of fish present in any reach of the river are controlled exclusively by the habitat limitations.

Pollution control efforts already undertaken in the US have essentially eliminated the grossest of pollution in the Nation's waters, such that there are no longer the widespread problems of fish kills due to discharges of contaminants. As indicated earlier, the emphasis in pollution control is shifting toward attainment of the ultimate in fisheries (zero pollutant discharge); eliminating the subtle effects of polluction, such as impaired growth rate, egg production, altered swimming behavior, etc.

As major efforts in this direction begin, as they are with the classification of streams and other waterbodies, the public will begin to realize that the improvements in beneficial uses of waterbodies obtained per dollar spent in pollution control will be greatly diminished. Figure 2 illustrates this concept as it shows substantial increases in cost for achieving lower and lower concentrations (to the chronic safe levels) of available forms of contaminants. At the same time, the impacts of the further reduction of contaminant concentrations on water quality - beneficial uses, become less. Because of the factors discussed previously (such as, reactivity, duration of exposure, etc.) however, it is not necessary in all cases to reduce contaminant concentrations to chronic safe levels in order to provide protection of beneficial uses of the water of concern. It is crucial with the current inflation and energy problems that funds available for pollution control be spent in such a way as to gain the most benefit per dollar spent. This will necessitate development of water quality standards which take into account environmental chemistry and physics of contaminants in natural waters, and the impact of contaminants on water quality - aquatic organisms.

HAZARD ASSESSMENT APPROACH FOR WATER QUALITY STANDARDS DEVELOPMENT

Lee et al. (1980b) have presented a discussion of the use of a "hazard assessment" approach for developing technically valid, cost-effective, and environmentally protective water quality standards. This approach employs the US EPA Red Book criteria to flag waters having potential water quality problems. If a water contains concentrations of total contaminants above these chronic exposure safe levels, the source(s) of the contaminants must then conduct a hazard assessment to determine if the apparently elevated concentrations impair beneficial uses of the water. In a selective, sequential testing scheme, such as is described by Lee et al. (1980a), the environmental chemistry-fate, including availability, and toxicology - organism response, and behavior of the contaminants in the system of concern are evaluated. If it is determined that the levels of contaminants present are or could be impairing beneficial uses of the water, then the source(s) must reduce their inputs sufficiently so as to reduce the hazard to an acceptable level.

Some advocate use of a statistical approach for establishing water quality standards. For example, the State of Colorado uses the mean concentration plus one standard deviation as an indication of a violation of a water quality standard for certain parameters in Colorado waters. This, as well as other simple statistical approaches, is not technically valid for use to assess violations of water quality standards or adverse impacts of contaminants on beneficial uses of waters. It is known that aquatic organisms are not concerned with the mean concentrations or, for that matter, with the standard deviation. As discussed above, the impact that a contaminant has on beneficial uses of a water depends on the amount of available forms of the contaminant and the duration of organism exposure.

This must be the basis by which technically valid water quality standards are developed. Further, water quality monitoring programs should be conducted to generate data of this type. The typical sporadic or regular but infrequent sampling will not generate the information needed to estimate potential impact. It is far better to conduct water quality monitoring programs for point source discharges with short-term, high-frequency sampling during periods exhibiting worst case conditions of the receiving waters, i.e., low flow, high temperature (or low temperature) than periodic sampling at weekly, monthly, or other infrequent intervals.

HIERARCHY OF WATER POLLUTION CONTROL

One issue with which water pollution managers have had to deal for many years is the dissolved oxygen concentrations in receiving waters downstream from wastewater treatment plants. Table 1 presents the general hierarchy of treatment that is traditionally followed for the control of contaminants in domestic wastewaters. At level A the focal point is directed toward floatable and settleable solids. The control program is usually accomplished through primary treatment involving sedimentation and skimming of floating materials in a settling tank. Appreciable amounts of various types of contaminants which can have adverse effects other than impairing aesthetic quality, are also removed through primary settling although primary emphasis of this treatment is to control materials which would have caused objectionable accumulations of contaminants in the receiving water sediments and, most importantly,materials that would float on the surface and be readily visible. With this level of treatment, a fishery will not likely be maintained within close proximity downstream of the effluent discharge unless the flow of the effluent is sufficiently small compared to the flow in the receiving water.

At level B, or secondary treatment, the emphasis in treating domestic wastewaters is traditionally directed toward control of oxygen depletion in the receiving waters and is accomplished by activated sludge or trickling filter biological treatment. The degree of dissolved oxygen depletion in receiving waters is a function of the degree of BOD (biochemical oxygen demand) removal and the relative flows of the receiving water and the wastewater. By tradition there are three levels of treatment that are usually considered in connection with BOD control. The first of these is the elimination of noxious odors associated with hydrogen sulfide, i.e., achieving from 0 to several mg/l DO in the receiving waters. No attempt is made at this level of BOD control to maintain a fishery below the effluent discharge, although some rough fish, such as carp and suckers, are usually

TABLE 1. WATER QUALITY MANAGEMENT FOR CONVENTIONAL DOMESTIC WASTEWATERS

Level	Problem	Control Method
A	Floating and Settleable Solids	Primary Settling
B	Oxygen demand	Secondary Treatment (Activated Sludge - Trickling Filter)
B_1	Sulfide odor	Trace - 4 mg/l DO
B_2	Maintain good fishery	4 mg/l DO minimum
B_3	Maintain ultimate fishery	Min. DO 5 mg/l (or 80% saturation) NH_3 $\tilde{<}$0.05 mg N/l NO_2^- ?

able to survive under these conditions.

For many years dissolved oxygen (DO) minimum levels on the order of 4 mg/l have been accepted as the level that should be present to maintain a warm water fishery. To maintain this dissolved oxygen level could be considered the second or intermediate level of BOD control. While the ultimate in fisheries may not be maintained in the vicinity of the discharge with this level of treatment, it is generally suitable for a good fishery within habitat constraints.

The third level represents the ultimate in BOD control. There are two basic approaches that are used. One is the maintenance of the US EPA Red Book minimum of 5 mg/l DO. The National Academies' committees concerned with dissolved oxygen concluded that any time the dissolved oxygen concentration was less than about 80% of saturation, the fish were being exposed to adverse conditions. While they are not killed at less than 80% of saturation unless the DO gets to a critical level, they are more susceptible to disease, tend to grow at slower rates, etc. Considerable controversy is developing today concerning the cost-effectiveness of maintaining the US EPA minimum 5 mg/l DO versus the more traditionally accepted 4 mg/l DO. This controversy is exemplified by the situation that has developed between the State of Ohio and the US EPA, where this State proposed a minimum water quality standard of 4 mg/l DO. The US EPA insisted that it conform to the Red Book number of a minimum value of 5 mg/l. The State of Ohio pollution control agencies filed suit against the US EPA for what they felt was an inappropriate decision which would lead to unnecessary expenditure of Ohio residents' funds. This situation is an example of the controversy that is going to be developing with respect to many of the US EPA water quality criteria. As discussed elsewhere, it is important to know what improvement in beneficial uses will be attained with increasingly stringent standards and whether the difference is of sufficient value to spend the money necessary to attain the standards or if the available funds would be spent more wisely in other areas.

NEED FOR RESEARCH

It was recognized by many in the early 1970s with the development of the water quality criteria provision of PL 92-500, that in order to bring about a cost-effective conversion of these criteria into state water quality standards, there would have to be a substantial research effort undertaken to provide the kinds of information necessary to avoid the kinds of implementation problems that exist today. Unfortunately, essentially concomitant with the adoption of PL 92-500, there was a significant curtailment in the research effort by the US EPA and other governmental agencies in two of the areas that were crucial to implementation of the US EPA criteria into state water quality standards, namely, aquatic toxicology and aquatic chemistry. The development of information in these two areas during the past half-dozen or so years has been far less than that necessary to begin to implement Red Book criteria into standards.

Another serious deficiency in our current state of knowledge relative to implementation of Red Book criteria into water quality standards is in the understanding of fish behavior. Until we gain a much better understanding of the factors that influence the presence or absence of fish in a particular region of a lake, river, stream, or estuary, we are going to continue to find a significant number of apparent anomalies of finding fish populations in regions which have apparently excessive concentrations of chemical contaminants which should be adverse to them. As discussed previously, there is also need for work in analytical procedures development for those chemicals which cannot currently be measured at or below criteria levels.

The US EPA management, in the opinions of many, has and continues to tremendously shortchange the public in leading them to believe that there is sufficient information available today to develop meaningful standards from the Red Book criteria.

During the past few years the public funding situation has worsened. The US EPA has focused almost all of its limited research funding for work in this area, on obtaining relatively small amounts of information (compared to the need for information) on the chemicals on the "List of 65" hazardous chemicals developed through the Consent Decree (US EPA et al., 1976). It is the opinion of the authors that the Consent Decree has done significant harm to the development of water pollution control programs in this country. It has diverted valuable resources away from the areas that need to be researched to implement contaminant control programs for the classical, known contaminants, such as, ammonia, chlorine, etc., and has forced the focus toward work on a group of exotic, rarely encountered contaminants.

CREDIBILITY OF GOVERNMENTAL AGENCIES IN THE WATER POLLUTION CONTROL FIELD

Local public pollution control agency staff and elected public officials in general have a relatively poor opinion of the ability of state and federal governmental agencies to develop technically valid, cost-effective approaches for achieving certain degrees of designated water quality in the waters of concern to a community. An example of this is the aforementioned report by the General Accounting Office (GAO) questioning the cost-effectiveness of Advanced Wastewater Treatment for domestic wastewater (GAO, 1980).

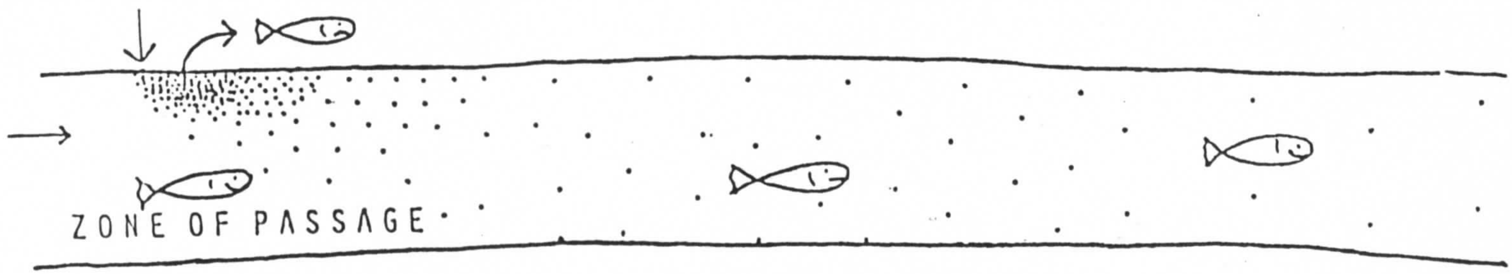
There is a general anti-big government attitude that exists among the public in general in all aspects of life, and is strongly reinforced in the water pollution control field by the US EPA-Washington, various US EPA regions, and state pollution control agencies which try to enforce the adoption of single, fixed numeric values for water quality standards upon which waste load allocations are developed. It certainly does not take much to convince the lay and semi-technically trained individuals that "big brother" in Washington and in the State House in some states is not utilizing the financial resources of the community at the local level to the best possible advantage, when they can readily recognize that the US EPA, through its water quality criteria, has assumed a worst case situation approach and that the concentrations of contaminants can in some instances be considerably above the US EPA Red Book criteria-based standard without significantly adversely affecting the beneficial uses of a particular water.

It is believed that it is fair to state that the US EPA water quality criteria and standards branch in Washington has low credibility among most state pollution control agencies. There are some, possibly most, members of state pollution control agencies (as well as local pollution control agencies) who look on the US EPA as not meeting its obligations in developing meaningful criteria that they can use. The US EPA-Washington has certainly been grossly negligent in this area in failing to provide guidance on how states should handle the numerous problems that are discussed in this paper, as well as others, in trying to implement worst case criteria into water quality standards. There is no question about the fact that this situation is leading to a large number of lawsuits against state pollution control agencies and the US EPA for failing to provide the kinds of information needed to handle these problems. Until the US EPA develops technically valid approaches for handling the various problems that are discussed in this paper associated with using Red Book criteria as state water quality standards, they are going to have little or no credibility in the water pollution control field and they are going to find that decisions on pollution control regulations in this country will be developed in the courts rather than by the technical community.

SUMMARY

In accord with PL 92-500, the US EPA has promulgated water quality criteria which are to be used as a basis for the development of state water quality standards. Many states are attempting to use these criteria values as their water quality standards. The fact that the criteria represent chronic exposure safe concentrations makes it inappropriate in most cases to do this. Figure 3 summarizes a fairly common situation that exists at point source discharges to a stream illustrating this point. Associated with most discharges is an area in which the effluent becomes completely mixed with receiving waters, labeled in Figure 3 as the Zone of Mixing. Contaminant concentrations here

Figure 3. Schematic Representation of Potential Impact of Non-Persistent Chemicals Discharged in Domestic Wastewater Treatment Plant Effluent



ZONE OF MIXING	EXTENT OF POTENTIAL CHRONIC IMPACT	CHRONIC SAFE CONCENTRATIONS
HIGH CONCENTRATIONS,	BASED ON US EPA RED BOOK CRITERIA (CHRONIC SAFE LEVELS)	BASED ON US EPA RED BOOK CRITERIA (CHRONIC SAFE LEVELS)
SHORT DURATION OF EXPOSURE,	DURATION OF EXPOSURE	
POTENTIAL ACUTE LETHAL TOXICITY,	ACCLIMATIZATION	
AVOIDANCE		

FISHERIES BENEFICIAL USE OF REACH OF RIVER CONTROLLED BY:

HABITAT CHARACTERISTICS	HABITAT CHARACTERISTICS,	HABITAT CHARACTERISTICS
POSSIBLE ACUTE LETHAL TOXICITY OF CONTAMINANT	POTENTIAL CHRONIC TOXICITY OR OTHER IMPAIRMENT DUE TO CONTAMINANT	

are higher than in surrounding waters and for some discharges can cause acute lethal toxicity if organisms spent sufficient time in the area. Concentrations in the Zone of Mixing are decreased by dilution and, to some extent depending on the chemical, by chemical reactions such as those discussed previously. Not infrequently, the shape of the discharge plume will create a Zone of Passage in which fish and other mobile organisms can avoid being exposed to the higher concentrations in the Zone of Mixing; as discussed previously, many organisms tend to avoid, if possible, elevated concentrations of certain contaminants. Even though concentrations in the Zone of Mixing can be acutely toxic, typical pelagic organism exposure would be expected to be short, minimizing potential adverse effect of the contaminant at higher concentrations. The fisheries-related beneficial uses of this portion of the reach of the river would be limited by potential acute lethal toxicity and/or habitat characteristics.

After dilution and reaction have reduced the contaminant concentrations below the acute lethal level, there is a stretch of river in which there is a potential for chronic toxicity based on chronic safe levels (Red Book criteria). It would be expected that this reach would be larger than the Zone of Mixing, extending until reactions of the contaminant and potential further dilution arising from additional water inputs caused its concentration to be decreased to chronic safe levels. Organism exposure here could be longer than in the Zone of Mixing, but the impact would be controlled by the concentration of available forms - duration of exposure coupling. It is also possible that fish could become acclimated to some degree and hence may be able to tolerate the potentially chronically toxic concentrations without adverse effects. Fisheries-related beneficial uses of this portion of the river would be limited by potential chronic toxicity as well as habitat characteristics.

The third zone begins where contaminant concentrations have been decreased to chronic safe levels based on Red Book criteria. Here, only the habitat characteristics limit fisheries - related beneficial uses of the water.

Not illustrated in Figure 3, but nonetheless an important consideration is the fact that the sizes - shapes of these zones continually change depending on flow, discharge rate and concentration, etc., and at times other factors, such as temperature. The concentration at any one point in the discharge plume can show large variations over short periods of time.

Given the above considerations and the fact that for some chemicals, concentrations cannot be reliably measured at the Red Book criteria levels, it is inappropriate to use a chronic safe concentration as a water quality standard, especially if exceeding the standard in any sample collected constitutes a standards violation. Instead, if there is question about the potential impact of a discharge on water quality, a hazard assessment approach should be used to estimate these characteristics of the particular system to determine if the hazard is acceptable in light of the beneficial uses and other limiting factors (such as habitat characteristics, public accessibility, etc.). It is only by using such a site specific approach, considering the characteristics of the chemical, receiving waters, and beneficial uses, that technically-valid, cost-effective, yet environmentally protective standards and contaminant control programs can be developed.

CONCLUSIONS AND RECOMMENDATIONS

The approach for implementation of the provisions of PL 92-500 for the 1980s and beyond is based on state water quality standards. By law, these standards must be based on the US EPA water quality criteria. Many states are using the numeric criteria values directly as water quality standards applied to the total concentration of the contaminant. There are numerous problems with this approach. While the US EPA has developed a variety of water quality criteria and will soon release a new set covering the Consent Decree List of 65 chemicals, the existing criteria (Red Book) were generally developed under or extrapolated to worst case conditions of the contaminant being in 100% available forms, and the organisms receiving chronic exposure; the criteria generally represent chronic exposure safe levels. However, many contaminants exist in natural water systems in a variety of forms such that usually only part of the total concentration is available to affect water quality. Concentrations of contaminants in many systems are continually varying as a result of variable rates of input, flow, dilution, and chemical reaction. Since organisms are affected by contaminants according to concentration of available forms - duration of exposure relationships, it can frequently occur that concentrations well above the chronic safe concentration level without there being an impairment of the beneficial uses of the water. The development and application of standards to provide technically valid, cost-effective, yet environmentally protective contaminant control programs, should be based on the concentration of available forms - duration of exposure relationships for each site of concern.

It is recommended that a hazard assessment approach be used to evaluate alleged violations of water quality standards to determine the water quality significance of apparently excessive concentrations of contaminants.

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