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ABSTRACT

This report discusses experimental systems that are used to conduct ecosystem research, with emphasis on the study of toxicants. The factors of ecosystem research including risk and cost are presented as are the various factors influencing ecosystems. As lined ponds have been used as an investigative tool for toxicant research at the Institute, there is a section which compares results from pond work to open water systems.

INTRODUCTION

Man's ingenious use of chemicals has enhanced his standard of living. When introduced, very little attention was paid to the deleterious effects of these chemicals in the environment, the by-products and impurities in their manufacture or the disposal of the wastes. Once in the environment, the chemicals, impurities, by-products and wastes, either by design or accident, can enter the aquatic regime. As water is used for drinking, agriculture, aquaculture, recreation and industrial processes, the chemicals can be ingested by man or influence his environment. The pathways of these chemicals through the environment, or their fate and impact, particularly in the aquatic regime, have significant importance to those using the water and those responsible for water management. This report will discuss various methods used to determine the fate and impact of chemicals in the aquatic environment.

When describing the fate and impact of a chemical on a system, the following nomenclature will be used. FATE will convey the concept of what happens to a chemical. This will include chemical, photochemical and biological action on the molecule, evaporative losses, the chemical being taken up by various biological entities and the chemical's intermediate and final locations in the system. Also the same consideration is used for any impurities and by-products of the chemical impinging on the system. IMPACT will convey the concept of an alteration of all or parts of the biota contained within the system. This includes those cases where the chemical will alter the environment producing a secondary effect, i.e., release of metals, pH changes, etc. The SYSTEM is that container or facsimile into which the chemical is introduced and includes all living, dead and inorganic material. To limit the ideas expressed in this report, only the lentic (non-flowing) portion of the freshwater regimes will be considered.

There are two basic approaches that can be used to determine the fate and impact of a chemical. One is to monitor the events related to the accidental introduction of a chemical which invariably occurs in a large outdoor aquatic system. This is often referred to as the case history method (e.g., 1). The other is the regulated release of a known chemical into a controlled system (e.g., 2). In this instance, the system can range in size from a test tube to an experimental lake.

The case history method has many advantages and several disadvantages; its main advantage being that the chemical is in the environment at realistic concentrations which were associated with the incident. Generally the water body is sufficiently large that numerous samples can be taken without the sampling interfering with the system. However, case history studies require that all methods be developed and at hand for collection, storage and analysis of samples. Samplers and analysts must have the necessary time for their specialty when the incident occurs with all aspects of the study prepared for immediate operation since it may be difficult to pick up threads of the event when there has been a time lapse. Some components of the system may be initially overlooked, which, on data analysis, may prove to be overriding factors. Usually there is no baseline data, needed for comparison of changes caused by the incident and the recovery of the system. Thus case history studies are essentially opportunistic. This contrasts with a controlled release of a chemical where all components that will be researched can be readied beforehand as the time of the event will be known.

In a study involving regulated releases, the size of the system will in part determine the type of results that are possible to obtain. Small vessels such as test tubes or flasks can be used to investigate certain aspects of the fate of a chemical, e.g., hydrolysis or the accumulation of a chemical by selected biota. This approach usually produces results that are measured over several days. The conditions such as light, temperature or nutrients are predetermined by the researcher. The large open systems (e.g., lakes) have an indigenous ecosystem and the necessary sinks for the chemical, and they are influenced by natural environmental conditions. An abundance of information can be generated but there are severe drawbacks to the use of large lakes for controlled release experiments. The system is extremely complicated, expensive to monitor and the chemical cannot be necessarily contained within the system. In addition there is no adequate control for comparison. Therefore, the optimum size for a fate and impact study involving regulated release of a chemical lies somewhere between the two extremes of a test tube and a lake.

EXPERIMENTAL SYSTEMS

Table 1 lists the various types of systems used to conduct aspects of fate and impact studies. These systems include test tubes, beakers, aquaria, limnocorrals, cassions, CEPEX bags, ponds and lakes. The surface areas range from 10^{-2} to 10^{7} m^{2}. The shape and use of test tubes and beakers are known, requiring no elaboration. Aquaria used for microcosm work are stocked in one of two ways. The first (9) is to put in water at a preselected nutrient level, then add selected organisms, such as an algal species, a zooplankter, one or two species of zoobenthos, perhaps a snail and maybe a small macrophyte. Then the chemical is added and the system is monitored over a two or three week period. Many aquaria can be made up in the same way. The second method is to take water from a natural system, place it in the aquaria, allow it to equilibrate, then add the chemical. Often lights are installed to simulate the sun.

Limnocorrals are enclosures usually made from thick plastic sheeting which are anchored in a lake sediment and the sides extend up to the surface of the water. During installation, a volume of the lake water and its biota is trapped within the enclosure. A cassion is somewhat similar to a limnocorral, but is circular and the sides are made of metal. The heavier material is used to provide extra protection against extreme weather conditions and wave action.

CEPEX (Controlled Ecosystem Population Experiment) containers resemble large balloons. These systems are used in deep water marine systems. With their balloon-like configuration, they are raised from a predetermined water depth to the surface of the water and supported from the surface. No attempt is made to put sediment in the bag as the experiment is for planktonic life forms.

Pond studies are usually of two distinct types. The first involves the use of established ponds where the chemical is added and the researcher does not worry about exchange of water or the removal of the contaminant from the system (10). The second type of experimental system involves the construction of excavations which are lined with continuous plastic sheeting. Sediment material of a desired type is then placed over the sheeting including the sides which are sloped to aid in retaining the sediment. Water is pumped in from a suitable source. When drawn from natural sources, the water will be accompanied by biota (for some studies, other life forms may be introduced, e.g., fish and macrophytes). As natural ponds would have exchange with the groundwater, many of the comments listed later concerning lakes will equally apply to them. For the remainder of this report, the term ponds will apply to those constructed and lined with a material such as polyethylene upon which an appropriate sediment type has been placed.

Partitioned lakes (11) are those bodies of water where a section of a natural lake is separated by a liner from the rest of the lake. The liner can be buried in the sediment and extended up to the surface. Therefore one part of the lake acts as a control for the other. Lastly, the use of whole lakes is self-explanatory.

FACTORS OF A FATE AND IMPACT STUDY

In an open aquatic ecosystem, three factors govern the fate and impact of a pollutant: the physical, chemical and biological aspects. The chemical aspects include hydrolysis and photochemical reactions, the water chemistry parameters of the system include nutrients, pH, etc., which affect the growth of certain biota. Indeed, the chemical may itself alter the biota. The biological aspects include the different life forms in the system which make up the natural food web. Also the action of the biota, especially the bacteria, can alter the chemical. The physical aspects include currents, waves, inflows (from groundwater, creeks, rivers, effluents, etc.), thermoclines and chemoclines that occur in limnology. Another series of the physical aspects are temperature, light regime, absorption on particles, weather and surface tension. The former aspects are difficult to replicate in enclosed systems (limnocorrals, cassions, CEPEX bags and ponds). In partitioned and open lakes, influences such as waves and currents will move the water and sediment about. Therefore, if a sampling station is being used to collect samples on a regular basis, the samples may not be comparable if the contaminated water and sediment have moved to another location or out of the system into another.

The volume of the system is an important factor. It must be large enough to support the highest trophic level of biota which will be the controlling predator of the food web in the system. The integrity of the system should be maintained until several life cycles of the smaller plankters are completed. A discussion of the relative sizes needed for this is given elsewhere (12). To carry out fate and impact studies or pathways investigations, the researcher requires a system that reflects natural conditons, yet not so complex that he cannot interpret his results.

1) Biota

In natural aquatic systems, or open artificial ones, after a period of colonization, there are complex biological communities. An unknown number of taxa interact directly (as predators and prey, as mineralizers and autotrophs, as competitors, etc.) or indirectly through other taxa. Populations wax and wane, invade or become extinct. At the other extreme, laboratory systems can contain a fixed number of similar individuals. Both of these extremes have their advantages and the researcher must balance the need for a system complex enough to allow the phenomena of interest to occur, yet be simple and stable enough that sampling be thorough and treatment effects discernible against background variation. To study community responses to chemical contaminants, several trophic levels, each represented by several species, should be present. The system should ideally be open to invasion so recovery or replacement of affected species can occur. The system should be large enough to allow all taxa of interest to undergo population processes, and to allow adequate sampling of all taxa.

2) Sunlight

This is an important factor related to the primary production of the system as well as the photochemical break-down of the added chemical and its metabolites as well as other natural chemicals. The biota experiences varying solar energy during the daily diurnal cycle and the amount of radiation it receives is influenced by cloud and ice cover as well as turbidity. Various configurations of light banks in indoor facilities simulate parts of the solar energies but this will only provide information on the potential of the system under the experimental conditions. Shading is another consideration in outdoor systems. This shading can come from trees or other obstacles near the experiment or from projecting parts of the system. In a series of enclosures used for controls or replicates, the degree of shading should be identical. Also the sides of an enclosure may attenuate or block light from entering from the sides.

3) Temperature and Seasonal Variations

Enclosures and open systems experience the natural temperature regimes. Ponds usually experience higher and more variable temperatures than larger bodies of water. Also lined ponds do not have thermoclines unless special features are built into their construction.

A natural consequence of low temperatures is ice formation during winter months. Long term fate and impact studies under Canadian climatic conditions require that these conditions be included as part of the investigation. The inflow of nutrients which are generally high during the spring run-off period should be included as part of the study.

4) Sediment Interactions

The sediment acts as a sink for persistent added chemicals and their metabolites as well as providing substrate for many life forms. In addition, the chemical may interact with or utilize humic material in the sediment. The chemical composition of the sediment, including mineral and organic content varies from site to site, and therefore is site specific. For certain enclosures, sediment can be added to cover the enclosure material to produce a natural littoral zone.

5) Risk

When studying the fate and impact of a chemical, its behaviour in a natural system is obviously not known. To place the chemical in an open system may cause a hazard and be considered therefore unwise. When the chemical is in an enclosure, the integrity of the enclosure must be a major consideration. Damage caused by aging of the material, vandals or weather conditions could release the chemical into the open environment. Although it may be diluted, the chemical could still represent a hazard. Equally important is the condition of the sediment after removal of the enclosure since if the chemical is somewhat persistent, it will remain in the environment. Thus, the system should be easy to clean up after the experiment. There may also be some risk to the experimental personnel taking samples on large water bodies or crossing large water bodies to get to the enclosures during periods of ice formation or thawing.

6) Costs

The cost of multianalysis from a large system may be identical to smaller systems if the same components were to be analysed. However, in a large system a greater sampling effort may be required to obtain the samples required to determine the distributions of the chemical and biota. Other cost differentials arise from the construction of the enclosures, the collection of samples and removal of the system. Costs of material may be the same for any of the systems to be constructed, as this would be dependent on the type of plastic used, etc. Construction at the site of ponds would be expensive as earth moving equipment would be needed. The set-up of CEPEX bags and limnocorrals requires scuba divers and sometimes ship assistance. Collecting samples in a limnocorral or CEPEX bag would require at least a boat to get to the site. Ponds require a mobile bridge, which is expensive. As one increases the set-up of the number of ponds, the costs rise very little, i.e., six ponds cost less per pond than four. Also, the cost of cleanup of a pond system would be less than for other outdoor systems if the chemical is found to be refractory.

In a laboratory-based study, only certain components are investigated and the experiment may have to be repeated each time another set of components of larger systems are to be investigated. In all the larger systems, the long-time costs should be lower than those in a laboratory as a wide range of analysis would be carried out encompassing all aspects of the ecosystem.

CHEMICAL TREATMENT OF SYSTEMS

The controlled outdoor systems described in this report cannot be used to mimic all possible types of releases of contaminants into the aquatic environment. Spills and water treatment (e.g., with a pesticide) are "one-time" occurrences and can be investigated by the above systems. To study the continuous or intermittent input of a chemical, imitate the leaching of components from soil into water or the continuous introduction of chemicals from an industrial site, the systems require more sophisticated ancillary equipment. As all systems of the outdoor variety are enclosures, there is no recycling of the water. There is also no dilution of the chemical other than that which occurs immediately after adding the chemical. Therefore, a simulation of a constant low level release of a chemical requires that either the water is constantly removed and filtered without altering the nutrients or biota, with fresh chemical being dosed back into the system, or the water being monitored continually and once the chemical concentration falls below a certain value, more chemical is added to bring the concentration to a pre-arranged level.

Another use of the fate and impact systems is to determine the effect of remedial measures (12). By using enclosed systems where the chemistry and biota can be examined over a period of time, one can ensure that the remedial measure causes less of an impact than the original chemical.

Finally, if the methods of sampling and analysis are well established, certain enclosure systems may be used to develop protocols to examine new chemicals before they are introduced onto the market. The results will provide information on lethal and sublethal effects as well as community response to the chemical and its breakdown products.

TYPES OF CHEMICALS THAT CAN BE INVESTIGATED

Chemicals that can be investigated, as grouped by sources are:

1. precipitation -
   - acid rain and pesticides
   - leachates
2. agricultural run-off -
   - nutrients and pesticides
3. municipal wastes (storm sewers)
   - oils and greases
   - metals
   - pesticides
4. industrial effluents and spills -
   - coal - phenols and polyaromatics
   - steel - phenols, polyaromatics, cutting oils and metals
   - oil refineries - phenols, hydrocarbons and sulphur compounds
   - chemical plants - variety of wastes
     - organic and inorganic acids
     - metals
     - aromatics and halogenated compounds

- food processing plants - oils and greases
  oxygen depletion
- refining industries - inorganic compounds
- paper mills - variety of compounds
- transportation - various chemical spills

SELECTION OF SYSTEM TO STUDY FATE AND IMPACTS

No one system can be expected to fulfill all requirements as described above, including replicates, controls, naturalness and low risk. Any enclosure should last for several years to maintain the integrity of the system as the biota may need an extended time to recover.

Most laboratory experiments, with their imposed conditions (light, nutrients, etc.) provide estimates on the potential of a system to act in a certain way. Outdoor systems, with their more complex ecosystems which experience natural climatic conditions and variable nutrient levels, provide an extensive amount of data but more important, trends. The biota in one area of Canada is not necessarily the same as in another, this being true even for lakes of close proximity. To make statements as to the fate and impact of chemicals, it is important to discuss trends which would be general rather than focus on a particular aspect such as a given biological species which may not exist throughout a broad zone. However, those aspects which make up the ecosystems, either experimental or natural, must be in all controls and replicates. The food web, even in a simple system, is complex and the larger the body of water, the more difficult it is to interpret the results.

It was the original intent of the report to show that ponds were a viable alternative to limnocorrals or CEPEX bags, in studying the fate and impact of chemicals introduced into the aquatic environment. However, as more aspects of each type of study was considered, it became apparent that ponds may be superior in many respects to other enclosures. On the other hand, it may be difficult to introduce thermoclines into ponds unless the ponds are modified substantially during their construction. The water temperature may be slightly higher than in larger bodies of water during ice-free period. These are two factors that should be considered when selecting a system. Otherwise, ponds have advantages over other systems. A number of them can be constructed in close proximity to provide controls and replicates. The sides can be covered with sediment so that there is a littoral zone around all sides with little of the liner exposed. The biota may not be the same as in large lakes, but similar taxa should or can be represented. If the ponds are allowed to acclimatize for some time before treating, with the biological and chemical measurements being taken regularly, the shifts in populations can generally be interpreted as being caused by the chemical rather than a space-predator pertubation that can arise in limnocorrals or CEPEX bags. Without large obstacles nearby, all ponds in a series will receive similar solar radiation. The heavy walls of cassions will prevent the enclosed water from receiving the same incident radiation as the nearby open waters. Using liners in ponds inhibits exchanges of the test chemical with the surrounding ground water, this permitting more reliable calculations of mass balances of the chemical. The pond liners and sediment cover reduces the risk of the chemical being dispersed over the environment. In case of a leak, the chemical will either stay in the sediment of the pond or in the soil adjacent to the pond, thereby facilitating cleanup. Other systems lack this feature. Although it is referred to above, it is well to emphasize that when a limnocorral or a CEPEX bag is used there is little time for the system to equilibrate before the addition of the chemical and the biota will change as many of the predator-prey relationships alter. When the chemical is added, and despite comparison of the controls with the adjacent larger water body, it may be unclear whether shifts in populations caused by the chemical are enhanced by simultaneous shifts in the biota.

The experimenter, when drafting the plans for the study must decide what aspects of the environment he wishes to include. The first consideration is whether all physical phenomena need be present in the system. If currents, waves and subsequent sediment movement are important, an open system like a sacrificial lake is needed. This would involve exposing a large area of the environment to the risk of the chemical being translocated. Concurrent operation of controls and replicates is difficult and, with specific sediment types and current vectors, generally make the study site specific.

On the other hand, the researcher may decide to concentrate on the chemical-biological fate and impact factors under the influence of the physical factors that are generated by the climate. The researches may, after the study is complete and sufficient data available, add in the parameters of dilution, currents, wave action and movement of the sediment to produce a general assessment.

The increases and decreases of nutrients in a system will influence the algae that will populate the system. Therefore, each enclosure or partitioned area will need the same nutrient levels on both sides of the dividing curtains for good comparisons. Ponds, with their similar drainage areas will have similar additions of nutrients in all control and replicate ponds.

Limnocorrals and similar enclosures may often have thick mats of filamentous material on the liners. This may dominate the oxygen and nutrient regimes. The sediment on the sloping sides of ponds produces a natural environment for the growth of periphyton and conditions are similar to those found in littoral or near-shore zones. However, large limnocorrals (45 m diameter) have been used successfully to determine distribution patterns of phytoplankton (5).

We have decided to focus our efforts on the chemical and biological aspects of contaminants using lined ponds. This is done realizing the test involves looking at the worst possible effects produced by the chemical as there is no exchange of water. With this condition, it is possible to determine at what concentrations the chemical is toxic and at what concentrations sublethal effects are produced. By using the ponds, a wide range of samples can be taken and used for specific analysis - applied research. Others, whose interests are in pure research (e.g., population dynamics) are encouraged to participate in the studies so that the maximum potential of the systems is realized. Finally, since the ponds are land-based, sampling can be done at any time. With fast turn-around time for results, appropriate ancillary field and laboratory experiments can be undertaken.

BRIEF COMPARISON BETWEEN RESULTS FROM PONDS WITH OPEN WATER SYSTEMS

The proof of an experimental approach to a pollution problem is to compare the results from an experiment to those that have been measured in an open environment. To date, oil, oil plus dispersant and 2,4-D have been investigated using large pond studies. Others have investigated permythrin (14), but this compound will not be included in the comparisons.

Oil

Much of the open environment research conducted on oil has resulted from case history studies of spill incidents. In most of these, measurements were initiated some time after the accident or when the oil impacted on the shore. An additional difficulty arises from the different types of oil that are spilled. However, certain comparisons can be made. Very little oil is found in the water column in an open environment, this partially being caused by dilution, but more probably by the general insolubility of the oil. This has been noted in pond studies, where most of the residual oil was found in the sediment.

After treating the water surface with oil, in the pond studies, there was a scarcity of surface insects, an observation reported for open-environment incidents (11, 13). The number of heterotrophic bacteria, estimated from plating experiments, increased in pond studies and in open environment experiments (15). Benthic organisms were affected in both pond and accidental spill studies (16). There were very few changes in the chemistry of the water in either open or closed systems (11, 17).

In addition to the above similarities, the ponds provided additional information on community structure and its subsequent changes. Effects on the proto- and meso-zooplankton, fungi and phytoplankton were continually monitored. There are no data on the effect of oil in an open environment on these components of the food web.

Biota returned to normal one year following treatment which was the same time observed for the restoration of the water biota in a secluded oil-transferring station which was susceptible to spills (18). Shoreline biota took longer to recover (19).

Oil and Dispersant

There are few publications related to the fate of oil and dispersant mixtures in the open environment or on the impact of the mixture. One paper (20) describes enhanced filamentous growths on rocks after the Torrey Canyon episod. The pond studies showed there was indeed an enhancement of filamentious algae on the sides and bottoms of the oil-dispersant treated ponds as compared to the control and oiled ponds. Laboratory tests indicated that the use of dispersant will aid in the rate of degradation of oil by bacteria (21). Such observations have been extrapolated to predict degradation in open water incidents. Apart from our pond study there are no reports in the literature which give the actual extent of oil degradation in open water accidents when dispersant has been applied.

2,4-D

The chemical 2,4-D has been investigated in many systems, both flowing and standing waters. In moving waters, the concentrations of 2,4,-D seldom reach those of ponds or standing waters which also received the recommended dosage. This is usually caused by dilution. The levels of 2,4-D and its persistence determined in our studies, in general agree with observation recorded in other pond systems. As in other systems, no changes in nutrients (P or N) were detected as the plants succumbed to the chemical. In our pond studies, it was observed that epiphytic growths on the plants increased as they came under the influence of the 2,4-D and before the plant collapsed to the bottom of the ponds. It was undoubtedly these ephiphytes which absorbed any of the nutrients which may have leaked from the plants. These epiphytes collapsed with the plants. If smaller ponds were used, the epiphytic material could have remained in the water column giving an apparent increase in the phytoplankton community.

None of the studies in the literature reported the presence of 2,4-dichlorophenol, a known breakdown product of 2,4-D. Analysis of the water samples from the ponds gave measureable concentrations of this chemical. It has been demonstrated that the unionized form of the phenol is more toxic than the ionized form (22) or the parent compound (23).

The oxygen regime was slightly affected by the plants decaying on the bottom of the ponds, but the ponds never went anoxic as predicted by laboratory experiments (24). Little or no effect was noted on the zooplankton community or on the total phytoplankton biomass. However, there were several species of algae that were affected (25), and this has been noted in laboratory experiments (26).

In flowing water systems (27), clams did not accumulate 2,4-D. In the pond studies, it was observed that the clams initially accumulated the chemical then eliminated it. This elimination occurred when the concentrations of the 2,4-D were at their highest levels.

Using sophisticated analytical techniques, along with unique extraction methods, we were able to measure 2,4-D in the sediment and representative fish samples from the ponds. Later we were able to collect sediment samples from areas not supposedly treated for several years in natural flowing and detect measureable quantities of 2,4-D. Also free-swimming fish from treated areas were collected some time after treatment, and 2,4-D was present in these fish. The pond studies indicated to us that most of the work reported in the literature was not carried out under Canadian climatic conditions, and that some of the conclusions previously arrived at should be confirmed.

SUMMARY

The above description of the various types of systems in which fate and impact studies of toxicants are conducted and their comparison to ponds, indicate that ponds are at least a viable alternative. This is based on the following considerations:

1. There is a low risk of contaminating the surrounding ecosystem with the toxic compound under study,
2. A number of adequate replicates and control can be used,
3. The ponds can be left to stabilize, allowing a natural predator-prey relationship to develop before treatment.

4. The ponds provide data that are similar to open systems but allow finer points to be amplified,
5. The water column in the ponds receives total incident radiation,
6. Sediment on the sides mimic the near-shore area,
7. By conducting a proper analysis of the components of the system, a reliable material balance can be calculated. This will show the distribution of the chemical in the system and give a quantitative measure of the amounts of the chemical removed (e.g., evaporation, biodegradation, etc.)

TABLE 1. Scale of Experimental Systems Used in Limnological Studies

	Typical Volume (m^3)	Typical Depth (m)	Typical Surface Area (m^2)
A: Laboratory Systems			
Test Tubes	10	0.1	10^{-4}
Beakers and Flasks	10	0.3	10^{-2}
Aquaria	10	0.5	10^{-1}
B: Outdoor Systems			
CEPEX[3]	60	15	4
Limnocorral[4] (small)	100	4	25
Limnocorral[5] (large)	$1.85x10^4$	12	$1.6x10^3$
Ponds (lined)[6]	170	0.85	200
Ponds[7]	680	1.2	1000
C: Natural Systems			
Small Lakes[8] (Clearwater Lake)	$5x10^6$	8.1	$7.2x10^5$
Lake St. Clair	$4.7x10^9$	4.1	$1.1x10^9$

TABLE 2. Factors Influencing Systems

Factors	Beakers, Flasks, etc.	Aquaria	Limno-corral Cassion	CEPEX	Lined Ponds	Part. Lakes	Open Lakes
Controls and replicates	X	X	X	X	X	X	
Integrity of enclosure	X	X			X		
Low risk of spreading contaminant	X	X			X		
Ease of cleanup	X	X			X		
Intense sampling			X	X	X	X	X
Exchange of groundwater						X	X
Realistic			X	X	X	X	X
Natural nutrients			X	X	X	X	X
Food chain	X	X					
Food web			X	X	X	X	X
Regenerate biota			X	X	X	X	X
Enhanced filamentous growth			X	X			
Thermo-and chemoclines			X	X		X	X
Artificial light	X						
Natural light			X	X	X	X	X
Seasonal variations			X	X	X	X	X
Currents, waves, etc.						X	X
Sediment		X	X		X	X	X
Cost	Low	Low	High		High	High	High

The above table was made up in a matrix form so that one may use numbers in ranking form of betwen 0 and 10. It is only for fate and impact studies of possible contaminants as other factors would be added for nutrient studies or other variables, e.g., the factors of risk would not be included.

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