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The economic impacts of PCB's in the Hudson River : a cost-benefit analysis

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THE ECONOMIC IMPACTS OF PCB'S IN THE HUDSON RIVER: A Cost-Benefit Analysis

by
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PART ONE
BACKGROUND OF PCB POLLUTION AND CONTROL

INTRODUCTION

The intent of this study is to examine the economic costs and benefits associated with PCB pollution and rehabilitation in the Hudson River. Although there have been many recent publications on the various economic and environmental costs of PCB pollution, as well as the costs to rehabilitate the river, few attempts have been made to couple the two. It is the purpose of this paper to quantify the economic and social costs of PCB pollution and control, and argue for specific methods of rehabilitation within certain guidelines.

The need for a discussion on this subject matter is crucial. Although pollution of the Hudson River has not increased dramatically over the past few decades, the results of previous pollution patterns have caused large economic and environmental losses which are still being felt today.

To date, the Hudson River and its basin are the largest fresh water sources immediately available to a city of 11.5 million people. These waters have the potential to provide not only recreational uses, but fishing and freshwater resources as well. Unfortunately, many of these potentials are inaccessible due to PCB contaminants. It is obvious that PCB pollution is a serious by-product of past industrialization and has had a severe effect on the economy which is continuing. Measures to control the PCB's have substantial associated costs that will impact directly on polluters and indirectly on consumers.

HUDSON PCB BACKGROUND

As mentioned, polychlorinated biphenyl (PCB) pollution is a by-product of certain industries. In this study we are dealing primarily with those PCB's omitted from two discharge pipes of the capacitator-manufacturing plants of the General Electric Company (GE) at Hudson Falls and Fort Edward, about 40 miles north of Troy, New York.

Those PCB's released accumulated on woody debris along the shores and in river-bottom sediment, in a backed up pool, behind the old Fort Edward Dam. When the dam was removed in 1973, a large migration of PCB's into the lower Hudson occured. Because of a drop in the water level of about 5 meters (a result of the dam removal), remnant deposits were recognized along the shores of the old dam. These deposits, woody debris and pulp residue, were highly contaminated with PCB's and vulnerable to any water level increases that would send them downstream. PCB's are transported downstream via sediment erosion, river bottom sediment, pollutants dissolved in or riding with the water, and floating debris.

In 1970, before the dam was removed, high levels of PCB contaminants were found in fish flesh in the Hudson River by author Robert Boyle. He had undertaken the project of sampling coastal gamefish for chemical pollutants including PCB's and found high levels in most of the fish with the highest level being in Hudson River striped bass netted during their spawning run in the Hudson near Garrison, New York. (1) After the dam was removed the DEC also found extremely high levels of PCB's in fish. (2)

Three major water level risings since 1973 have shifted PCB's in the Upper Hudson in downriver surges directly corresponding to higher levels of PCB's found in fish and sediments downstream following the floods. (3) Many of the PCB's that have shifted downstream have settled in river-bottom areas known as hot spots.

REGULATORY FRAMEWORK

As a result of PCB contaminants being found in the river, the New York State Department of Environmental Conservation (DEC) closed all fishing along the river from Hudson Falls to Troy. Commercial fishing in the Hudson was prohibited and health advisories on fish consumption were issued (1976). These acts immediately followed the Congressional passing of the Toxic Substances Control Act banning the manufacture of PCB's and prohibiting all uses with the exception of completely closed systems.

In 1978, some restrictions on commercial fishing in the Hudson were lifted, however complete restrictions still apply to striped bass and American eel. Currently, the EPA's accepted PCB tolerance level in fish is 2.0 parts per million (ppm). (4) Both the striped bass and American eel have PCB levels far exceeding this tolerance level.(5)

REHABILITATION HISTORY

After the findings of PCB's in the river were made public, the DEC began proceedings against GE for violations of state pollution laws. The case was concluded in a settlement with GE contributing $3 million for research, matched by state funds with the stipulation that GE could not be charged by the state with the cost of rehabilitation for the Hudson.(6)

The proposed rehabilitation encompassed dredging river-bottom hot spots and encapsulating the contaminants in a landfill. The original estimate of $27.8 million for the cleanup was far exceeded by later estimates that included additional contaminated areas. There have been several proposed sources for these funds over the years, but with the creation of Superfund, federal funds may now be available for Hudson reclamation. The Superfund money will become available upon the conclusion of a complete EPA examination and study of the problems for rehabilitation in the Hudson (now considered to be at the end of 1992).

Since the EPA was not involved in the original suit against GE, it can seek reimbursement from GE for all cleanup costs. The EPA recognized GE as the responsible party in 1981.(7) With the funds no longer limited, the state, once again, estimated the cost of the total PCB cleanup, not simply specific hot spots. Currently, the cleanup will cost about $280 million with the cost possibly being paid by Superfund and reimbursed by GE.

Because of its potential liability, GE has searched for alternatives to the dredging process. GE proposes eliminating the PCB's by biodegradation using aerobic and anaerobic organisms. Both dredging and bioremediation are controversial in their cost and effectiveness.

SCOPE OF THESIS

The scope of this paper will encompass the following areas: Part Two will deal with costs associated with PCB pollution and control. The first section will explain the difficulties inherent in any attempt at cost measurement. Some of the issues that will be mentioned include the lack of specific critical variables and relationships, the uncertainties concerning the effects of PCB's and rehabilitation processes, and the absence of valid dollar comparisons for costing purposes.

Part Three will begin with a discussion on valid alternatives for cleanup and their associated costs. Part Four will examine the general costs of pollution to society. The effects on the environment and pinpointing ecological deterioration will also be related. The economic, environmental effects section will not only comment on the present state of affairs, but will show the far-reaching hand of PCB's in the Hudson. The next section will be a rudimentary trade-off analysis of alternative methods for rehabilitation and the crucial factor of time.

Part Five of this study will be concerned with "The Future". This will focus on possible solutions and/or alternatives to the present system of pollution control. The economic impacts of PCB's and the importance of a quick, effective solution will be discussed in general terms.

LIMITATIONS OF STUDY

Although PCB's can upset the balance of nature in many ways, this study will be limited primarily to effects on the Hudson River and its basin. However, within the study further limitations will be referred to. For calculation of cost figures, concentration is placed primarily on measuring physical damages. This is hard enough because the relationships between the quantities of pollutants and resultant damages are both complex and highly variable. Because of the extreme difficulty in quantifying non-physical damages such as the loss of aesthetic values and some recreational activities, these "losses" are omitted from total cost calculations.

It is the objective of this examination that it may serve as a base for future study. In its present form, it is intended to be a statement of a regional problem with supporting evidence to document the severity of the issue. It is hoped, therefore, that it will serve as a foundation upon which feasible solutions to the economic problems of PCB pollution and control can be built.

PART TWO
COST-BENEFIT MEASUREMENT

METHODOLOGY OF COST MEASUREMENT

The decision problem of PCB pollution in the Hudson River is ultimately whether we, as an economic society, undertake no action or proceed to reduce PCB's via dredging and/or bioremediation. A decision between alternative methods requires a balancing of costs imposed on society against the values of benefits. Thus the calculation involves a comparison of net cost with net benefit for each option.

In this analysis, costs will be defined as what society has to pay to support a specific choice, and benefits will be defined as what society will gain, whether it be in monetary or aesthetic Values. Since quantifying these values requires data, time and extensive analysis, some of which is inaccessible within the scope of this examination, we will be concentrating on numeric values immediately available. These will include estimated costs of cleanup and estimated damages to specific industries, i.e., commercial fishing and recreational use of the Hudson. Aesthetic values will be discussed in general terms as a benefit or cost for each specific option.

Currently there are many difficulties of cost and benefit measurement which may undermine the validity of cost-benefit analysis or similar methodology. Uncertainty in many critical variables plays a key role in limiting the conclusions that may be drawn as to the best strategy for controlling PCB's. These variables include current and future demand and supply for various industries (i.e., commercial fishing), geological movement of PCB's in the Hudson itself, and the price and efficiency of pollution control.

EXTERNALITIES

In order to assess a valid computation of the costs and benefits for the whole economy, we must internalize the externalities associated with individual industries. In this situation, the PCB pollution would be a negative production externality for the commercial fisheries. It is a factor which directly and negatively affects their production but cannot be traded on the open market, i.e., a factor the fisherman have no control over.

At the time of the pollution there were poorly defined property rights stating that the fisherman had a right to clean water. "Poorly defined property rights lead to inefficient production of externalities, meaning that there would be ways to make both parties involved better off by changing production externalities." (8) In this case the increase in the cost of fishing associated with an increase in pollution is a social cost.

In a simple model of Plant A emitting PCB's that affected Plant B and Plant C's production, we would calculate the efficient output levels of PCB's so to maximize the sum of the profits for all involved - that is, minimizing the total social cost of the pollution. This would be done by "merging" the two plants (internalizing the externality), and thus finding a level of PCB emission that is best for the whole unit. Similarly, in this analysis we will "merge" all of the agents involved into a common unit, our economic society.

Since it was estimated in the study *Contaminants in the Hudson River Striped Bass: 1979-1985* by Slaon and Horn (1986) that the PCB's will not deteriorate to an acceptable level naturally until 2020, (9) we will treat existing PCB's as though they are still in production and will possibly remain unchecked for the next 30 years. Thus we can view PCB's as a negative production externality and calculate a socially optimal amount of pollution by minimizing our social costs.

UNCERTAINTY

As we have mentioned previously, uncertainty is a critical factor in the decision-making process. In this specific case, we find uncertainty prevalent in the following areas: 1) the effects of PCB's on the Hudson River environment, 2) the effectiveness of proposed programs, 3) the possibility that time delays will create more problems and 4)the economic outcomes for industries damaged by the pollutants as well as the polluters themselves. Because these uncertainties exist, there is a corresponding risk with each area. These specific risks initiate the discussion of risk for the society in general and the assumption that a reduction in risks is the most efficient alternative.

The effects of PCB's on the Hudson River environment are controversial. It is known that fish such as the striped bass store PCB's in their fatty tissues, but in what quantities for how much time through how many generations is not known, (10) The future toxicity of species in the river is questionable as well as the levels of PCB's that will remain in river bottom sediment. These uncertainties will remain even after reclamation of the river has been accomplished. (11)

The health effects of PCB's on humans are widely disputed. Some industry officials feel that PCB's are probably harmless to humans (12) However, the EPA views PCB's as toxic and persistent and "that the available data shows that some PCB's have the ability to alter reproductive processes in mammalian species", (13) as well as having cancer causing potential. (14) With this in mind, the question becomes which method of removing PCB's is best. At this point, both bioremediation and dredging come under attack.

Dredging, as of yet, has not been proven to be the perfect solution. Those opposed to dredging speculate that it may disrupt the aquatic environment and/or increase the levels of contamination by stirring up PCB's buried in the riverbed and consequently create new problems downstream. (15) Likewise, the effectiveness of bioremediation is also disputable. Although the process of bioremediation has proven promising in controlled laboratory tests, it cannot be determined if it will be effective in the river itself. (16)

It has been proposed that the 90's will be a high flow decade for the river, and if this were the case, PCB levels could stir from their present positions to other areas. (17) An event such as this would require additional research to find new hot spots (if the PCB's were not too widely dispersed) which would yet again increase the amount of time necessary for a clean-up. Floods and high river flows also present the possibility of increased PCB levels in aquatic life. It has been shown that PCB levels in fish increase with greater water discharge, (18) Therefore, the factor of risk associated with time delays is valid when considering the potential damage to aquatic life and the possibility that cleanup could be made more difficult, if not impossible.

There also exists a degree of uncertainty for the economic recovery of industries damaged by PCB's. Those industries include commercial fishing, recreational use of the Hudson and recreational angling. For many years the Hudson River has had a reputation of being polluted. Even if the PCB's are removed there is no guarantee that the reputation of the river will be removed as well. The public may be hesitant to eat fish associated with the river and may not return to use the Hudson's recreational facilities.

For GE, the situation is more complex. If dredging were the option chosen to clean the river, there is the potential financial liability for GE. The cost of the proposed dredging project is enormous - an estimated $280 million. Obviously, GE would like to avoid a cost such as this which could have ramifications for the company. Besides affecting profits, layoffs and higher prices would not be improbable. Additionally, the environmental impact of pollution is uncertain. In the case of uncertainty, the individual pollutor (GE) will form expectations on the government policy instruments to be used. These expectations affect the individual firms environmental policies. Therefore, an individual pollutor will experience costs of adjustment when environmental policy is changed as it has over the years with PCB control in the Hudson. Because abatement capital cannot be adjusted to new policies quickly, these costs will relate to capital costs (19) -- especially when dealing with the power-generating industry whose prices are sometimes regulated.

PART THREE
PROCESSES FOR REMOVAL OF PCB'S

Over recent years, there was a noticeable decrease of PCB levels in fish found in the Hudson River. However, the levels have reached a plateau with no significant changes in the past few years. (20) This would seem to indicate that the river has cleaned itself as much as possible of any significant amounts of PCB's and that further drops in levels could only be over a considerable length of time. (21) Therefore, to eliminate PCB's from the river in a timely manner', a method other than natural river cleansing must be relied upon.

DREDGING

As a proposed alternative for cleaning up the PCB's, dredging has been considered the most likely to succeed. "The (Hudson River PCB Settlement) Advisory Committee made its recommendation in favor of dredging in 1978. Nothing that has come to its attention in the ensuing 11 years has caused it to waver in this position." (22)

The process would be similar to that done by the Department of Transportation when they dredge the river for channel maintenance. "(The) proposed hot spot dredging plan is the outgrowth of considerable experience in dredging the navigational channels." (23) PCB's settle in river-bottom sediment and remnant deposits along shores where the water levels have dropped. Hot spots would be identified, and the river-bottom sediment and remnant deposits would be dredged and removed from the river and shores. The material, once dredged, would be encapsulated in a landfill. There are many different processes for encapsulation, the process the most favored is that of submerging the PCB-laden material in cement where leakage will not be possible. (24)

It is estimated that dredging will reduce the transport of PCB's by 20% over the next 10 years. (25) The process, once begun, would take two constructional seasons (approximately three years) to complete. (26) Costs for removal of PCB's by dredging and encapsulation are approximately $280 million.

BIODEGRADATION / BIOREMEDIATION

The option preferred by General Electric for removal of PCB's is a process called bioremediation. (27) This uses nutrients and organisms to accelerate the slow natural biodegradation of PCB's. The theory behind the process is that the removal of PCB's can be accomplished without further environmental damage and at a smaller cost. (28) The process of bioremediation has proved promising in controlled laboratory tests. Currently the two methods GE is working on involve aerobic and anerobic organisms. (29)

Using aerobic organisms to deteriorate PCB's has been studied over the past 15 years. Although the organisms act very quickly in degrading PCB's, the limitations of these organisms is that they can only degrade lightly chlorinated PCB's. They also require isolation and continual aeration (as they are oxygen-thriving organisms). The isolation would mean the complete sectioning off of parts of the river to be cleaned. (30)

Anerobic organisms have only recently been discovered to help deteriorate PCB's to a less toxic form. Although they do not entirely degrade the PCB's, they can "pluck" chlorine from the PCB's molecules, converting them to a less toxic PCB. (31) Anerobic organisms are used by injecting nutrients into the sediment. This process is very slow Compared to the aerobic organisms. It can take from several weeks to as much as six months for a full cleanup in small, controlled, laboratory experiments. (32)

Neither the use of aerobic nor anerobic organisms has yet been proven effective in the river itself. GE is about to begin in-river tests and optimistically estimates that in a three-year period they will begin engineering on a large scale. (33) They have no true cost estimates for a complete cleanup, but they will contend that the bioremediation process using aerobic organisms would be at a comparable cost to dredging and that the anerobic process would be "considerably less" expensive.(34)

PART FOUR
GENERAL COSTS TO SOCIETY

COMMERCIAL FISHING

The industry of commercial fishing has been hit very hard by PCB's. All commercial fishing in the Hudson River was banned in 1976 but the DEC lifted restrictions in 1978 to only include the striped bass and american eel. The rationale behind the current restrictions is that these two species, unlike others that migrate to the Hudson for short periods of time, are in the river long enough to absorb dangerous amounts of PCB's. (35) In 1986, the Department of Environmental Conservation prohibited the "commercial and recreational taking, possesion and sale of striped bass statewide." (36) Consequently, commercial fishing for striped bass has all but been eliminated in the New York City area (the exception is limited commercial fishing of striped bass was allowed as of 9/90 on the east end of Long Island). Table A outlines PCB legislation affecting Hudson River fisheries.

Other commercial fisheries have also suffered greatly due to the PCB's. "New Yorkers are chary about eating even the fish experts say are safe. Restaurants on the banks of the river list on their menus Idaho trout, Atlantic salmon, Boston scrod -- anything but fish from the Hudson." (37) Meanwhile, enormous growth

PCB LEGISLATIONS (38)

1973	FDA sets tolerance level of PCB's in fish at 5.0 ppm.
Feb. 25, 1976	DEC prohibits all fishing from Ft. Edwards to the Troy Dam, the taking of American eel from the entire river and commercial fishing except for American Shad, Atlantic Sturgeon greater than four feet in length, and goldfish from Troy Dam south. Health advisories issued.
Aug. 3, 1977	DEC prohibits commercial fishing for American eel in Harlem River and East River.
May 22, 1984	FDA adopts new PCB tolerance level of 2.0 ppm.
May 6, 1986	DEC prohibits taking, possession and sale of striped bass throughout marine waters in New York State.
Sept. 5, 1990	DEC reopens limited commercial striped bass fishery

on the east end of Long Island for fish 24 to 28 inches long.

in the river's population of striped bass threatens to overwhelm an already suffering commercial shad fishing. Nets put out for shad are jammed and ripped by contaminated striped bass that the fisherman throw back into the river.(39)

Until the PCB levels in striped bass and other species reach 2.0 ppm (that tolerance level designated by the FDA), the affected commercial fisheries will have no chance to recover. However, there exists sufficient demand for these species, and if some process of treatment enables the levels to drop, there lies an opportunity for the industries to rebound.(40) Processes such as dredging and bioremediation may substantially lower the downstream transport of PCB's. As mentioned previously, the dredging proposal is estimated to reduce downstream flows of the toxin by 20%. Unfortunately, it is not known how these reductions will affect fish flesh.(41)

Currently, any alternative is preferred to reduce the PCB levels. Several studies have indicated that at the current rate of PCB decline in fish, it will take close to 33 years for PCB levels to be reduced by 50% for fish in the Hudson River. (42) Striped bass and black bass, for example, may still have concentrations well above the 2.0 ppm standard in the year 2020. (43) Given these rough estimates of time allowances, it would seem that any process that could reduce PCB levels in the quickest manner would be welcome.

Once the river has been cleaned and PCB levels in fish reduced, fishing restrictions on striped bass and American eel can be lifted, enabling full commercial fishing to be active. Not only will it stimulate the striped bass and the american eel industries, but also the improved water quality could have far reaching effects on New York fish industries as a whole. If New York waters are perceived as cleaner, all fish and fish products from these waters will seem more desirable in the market that they exist now.

As the river improves, more jobs will become available to those previously unemployed as a result of PCB contaminants.

The DEC summarized in its "Regulatory Impact Statement" accompanying the prohibition of striped bass possession that the economic losses may exceed $12 million for the striped bass industry. (44) This includes Long Island commercial fisherman, charter boat operators, fish wholesalers and fish retailers. The lost opportunities in commercial fishing for striped bass and american eel for the Hudson River alone are estimated to have an annual economic impact of $1 million each. (45)

RECREATIONAL FISHING

The presence of PCB's in the Hudson River has not only affected the commercial fishing industry, but to an almost larger extent has damaged the economy in the area of recreational fishing. Few anglers are pursuing the abundant population of fish in the Hudson because of its historical reputation concerning pollution, as well as 15 years of health advisories warning of toxic contamination. (46) The Hudson River has enormous potential for attracting recreational anglers. However, because PCB's are contaminating the fish these opportunities are forgone as well as the economic benefits accompanying them.

Recreational fishing (angling) has proven to be very popular in the Hudson, especially catch-and-release or "Trophy" angling. Some local anglers in the tidal Hudson area (from Troy to Battery) recognize it as a scenic resource and pursue catch-and-release angling even though they have been warned for 15 years about contaminants. (47) Unfortunately, the fishery from Fort Edward to Troy will not be opened until levels of PCB's in fish flesh are much lower than at present.

When PCB levels decrease, the Upper Hudson will become a prime candidate for large-scale recreational angling. Already there is interest in opening the fishery from Fort Edward to Troy for catch-and-release angling. Since there has been no legal harvest, the fish in the Upper Hudson are growing to appealing sizes and will be considered "high quality" when the fishery reopens. (48) Not only will fish in the Upper Hudson attract anglers to that area, but improved fish passages at several dams upstate will allow new areas of the Hudson to be opened to recreational fishing. (49)

Using popular fishery management for the area from Fort Edward to Troy it is expected that the 4000 acre stretch of the river would support 25 angling trips per acre per year. (50) "At $24 per day, actual angler expenditures (average expenditure per angler day from the New York Angler Survey), $2.4 million will be generated annually into the New York economy by anglers fishing this River stretch. Using a sportfish multiplier of 2, total economic impact will be $4.8 million annually." (51) However, this will not occur until the PCB levels decrease to levels acceptable to the New York State Department of Health.

The lower Hudson has the potential to be a productive warmwater fishery a few hours drive from a city of 11.5 million people. There are abundant supplies of striped bass and shad, as well as black bass which have become very popular due to national tournament publicity. The DEC feels it is reasonable to assume that when PCB's are reduced, recreational angling in the tidal Hudson will at least double or triple. (52)

In 1976, J. Douglas Sheppard, the Supervising Aquatic Biologist for the DEC estimated the annual angler trips from the Troy Dam to the Tappan Zee Bridge to be 165,000. (53) Doubling or tripling these figures for potential lower Hudson fishing becomes an economic impact of $15.84 million to $23.76 million per year (after a multiplier of 2 is applied.) (54) Averaging these two estimates assigns the forgone recreational angling opportunities for the Lower Hudson $19.8 million annually. (55)

To summarize the forgone opportunities in the Hudson River because of PCB contamination: (56)

Upper Hudson: 100,000 angler trips annually - $4.8 million per year

Tidal Hudson: 412,500 angler trips annually - $19.8 million per year

Total: 512,500 angler trips annually - $24.6 million per year.

When PCB levels have decreased and recreational fishing is unrestricted, these economic losses should be recoverable. Either dredging or bioremediation would be acceptable solutions for enhancing recreational angling.

GENERAL ELECTRIC

GE is in the unique role of the polluter regarding PCB's in the Hudson River. Because of EPA rules for Superfund that state the "polluter pays" for rehabilitation, GE has investigated alternatives for cleaning up the river. Ultimately, the funding for restoration will come from GE, therefore the company would like to find the most effective process at the smallest cost.

After evaluating the alternatives, researchers at GE have been pursuing the bioremediation process for several reasons. Not only do they feel that it will be more effective using natural processes, (57) but there is also the additional benefit of having a method of removal that could be used in similar situations they are involved with in other parts of the country. (58) Currently GE is investing approximately $5 million annually in their research for bioremediation. (59)

The dredging proposal has many negative points in GE's opinion, (60) It involves physically removing the PCB's from the river but not eliminating them. They argue that this process of removal may stir the PCB hot spots and shift them downstream causing more damage to the river and aquatic life. These problems combined with an estimated price tag of $280 million makes GE feel this is not a valid alternative, (61) If the dredging process were to be approved, GE would be potentially liable for the $280 million. A payment of this amount would affect the profits for the company and be a straight loss.

Alternatively, the bioremediation process using anerobic organisms would be "considerably less" expensive according to GE. (62) Not only would the dollar amount for rehabilitation be lower, but once the process has been proven successful, it can be used in other situations. This cost becomes an investment towards other projects and is also potentially marketable.

GE would like the cleanup to involve bioremediation, however they do intend to continue their research even if the dredging proposal is approved. The amount of money designated for this project would be cut back, but by how much is uncertain. (63)

GE's interest lies in eliminating PCB's at the lowest cost. For them, this leaves bioremediation as the best alternative. It could be considered a partial investment as opposed to a total loss of money. However, as with most investments, there is a risk involved. In the case of bioremediation, the risk lies in the possibility that the process will not work, and that if it does, it may not be effective for use with similar cases.

SOCIAL COSTS

Although it is generally difficult to quantitatively measure, the social cost to the consumer is one area of concern that is widely publicized in today's media and which has been qualitatively explored. Proponents of legislation that would curb pollution advocate that our economy would be better off in a material sense if pollution were substantially reduced.

Companies normally do not include in the cost of pollution such externalities as water pollution which impact directly on aquatic life, recreational opportunities, aesthetic values and health. Thus, they pass on a heavy "hidden" cost to the community which is met by either public spending or destruction of the amenity.

The social costs related to PCB's effects on aquatic life are various. As mentioned previously the PCB's in fish flesh have effectively eliminated certain fish from the market in the New York area, as well limiting recreational angling. We must also include as a social cost the unquantifiable damages to aqautic life itself. It is not known what exactly PCB's are doing to aqautic species and what effects this will have on future generations. The EPA's research indicates that "Deleterious effects of environmentally important freshwater invertebrates from PCB's have been demonstrated ...The survival rate and reproductive process of fish can be adversely affected in the presence of PCB's"(64)

Recreational opportunities lost due to water pollution, PCB's included, are angling, swimming, boating etc. Although PCB's are not solely to blame for losses in some activities (the Hudson has had a reputation of being polluted for many decades), they are the most publicized and responsible for much of its current reputation.

To estimate the social costs of water pollution and its effect on recreational opportunities, one must work backwards and calculate the cost of putting the environment back to its original state. One such study was performed for the Delaware River (Davidson, Adams and Seneca). (65) Benefits included increased recreational use of the river for boating and fishing for the period 1965-1990. Costs were based on that amount necessary to improve water quality to such a point as to make the river suitable for such purposes. It was found that it took very modest prices for recreation to cover the costs of improvement, i.e., it would have paid to clean up the Delaware considerably in 1965 if the use for one day's boating was worth $2.55 to the boater. While not a substantial sum, it nevertheless represents a cost to society which would not have to be paid in the absence of pollution.

PCB's have not directly affected the aesthetic value of the Hudson. There are no wastes floating or foul odors from them. However, the PCB's directly affect our perception of the river. Although they are not visible, one cannot help being aware (due to the highly publicized nature of the contaminants) that they are there. This alone decreases the aesthetic pleasure derived from viewing the river.

The health effects of PCB's are numerous. Although most people do not drink water directly from the river, there is a potential risk if someone were to eat fish taken from the river. The health effects of PCB's on mammals, as noted by the EPA, are listed below.(66)

(From Aug 25, 1982, Federal Register Statement) EPA concludes that PCB's are toxic and persistent.

EPA agrees that choracne occurs in humans exposed to PCB's. Although the effects of choracne are reversible, EPA does not consider it insignificant. EPA finds that reproductive effects, developmental toxicity, and oncogenicity are areas of concern and may produce effects in humans exposed to PCB's.

Available data show that some PCB's have the ability to alter reproductive processes in mammalian species, sometimes even at doses that do not cause other signs of toxicity. Animal data and limited human data indicate that prenatal exposure to PCB's can result in various degrees of developmentally toxic effects.

Available animal studies indicate an oncogenic (cancer-causing) potential (the degree of which would depend on exposure).

The true risk associated with PCB's in the Hudson River is that they may eventually end up in humans. The EPA additionally stated that "PCB's can be concentrated and transferred in freshwater and marine organisms. Transfer up the food chain from phytoplankton to invertebrates, fish, and mammals can result ultimately in human exposure through consumption of PCB-containing food sources." (67)

Although all of the above factors merit significance in that they impose a burden on society, the health costs and risks must be considered of paramount relative importance in any discussion of the diseconomies caused by pollution emission.

REHABILITATION COSTS

The most attractive features of the dredging alternative are that it is presently recognized as the best option to accomplish the task, and if approved, could be implemented immediately. Given that time is a crucial factor involved in the cleanup, this method has an advantage over bioremediation. Below we will discuss the annual economic costs of PCB's in the Hudson River under the assumption that the dredging alternative is approved. These costs do not include the Unquantifiable social costs such as aesthetic values and health risks discussed in the previous section.

If the dredging process were to be approved immediately, it would take approximately 1 year for the work to begin, (68) This year (year 1), in cost terms is equivalent to every year that no rehabilitation has been done. The estimated quantifiable costs for this year are as follows: (69, 70)

Activity	Annual Value

GE Research	$5.0 million
Hudson River recreational angling	24.6 million
Hudson River commercial fishing	2.0 million
Marine striped bass impacts (recreational and commercial)	12.0 million
Total	$ 43.6 million

Year 2 and 3 of the dredging alternative are those years that the rehabilitation would be taking place. Each of these years would have many of the same components in cost as year 1, with the addition of $280 million assigned to cleanup costs minus research expenses for GE ($5 million annual value would be purely investment should they choose to pursue it).

Activity	**Annual Value**
Year 2:	
Hudson River recreational angling	$ 24.6 million
Hudson River Commercial fishing	2.0 million
Marine striped bass impacts	12.0 million
Year 3:	
Hudson River recreational angling	24.6 million
Hudson River commercial fishing	2.0 million
Marine striped bass impacts	12.0 million
Dredging	280.0 million
Total	$357.2 million

The total economic impact in the first three years would be $400.8 million.

The bioremediation process, as of yet, has no set price tag. (71) The cost is estimated to be near that of dredging using aerobic organisms, however, GE is concentrating on research with anerobic organisms. Using this process the expense would be much lower than either biodegradation with aerobic organisms or dredging.

Unfortunately, the anerobic method is still in the initial testing phase. As mentioned previously, large-scale testing is not expected to occur for another 2 years and optimistically speaking, bioremediation would not be ready to rehabilitate the river for an additional 4-6 years, and could take up to 2 years to complete.(72)

The economic impacts, should this process be approved tomorrow are similar to those of dredging. Since there is no value of the cost of bioremediation using anerobic organisms. We will not include this cost in numeric values of estimated costs for the time period for cleanup. The economic costs for cleanup, not including the process itself would be those annual values for an eight year time period (using the smallest time frame).

For an eight year period at an estimated $43.6 million annually, the total economic cost minus the cost of cleanup would be $348.8 million (assuming GE continues research throughout the project).

Even at the low figure of $100 million for the bioremediation alternative, for a total of $448.8 million it is easy to see that in general figures the dredging alternative at $400.8 million is the best method.

However, our results are contingent upon the fact that one method or another would be approved immediately. If, for example, approval were delayed for 5 years on either process the values would alter in favor of bioremediation.

Cleanup efforts will be concentrated on large areas of river-bottom contaminants (hot spots). Once either bioremediation or dredging is completed, there will still be a substantial amount of PCB's in the river. (73) The PCB's will be those not located in hot spots. These PCB's, combined with existing levels in fish flesh make it difficult to determine when commercial and recreational fisheries can be reopened. With either method there will still be a post-cleanup period before the river is completely rehabilitated. This time frame could be anywhere from 10-30 years. It is not necessary to calculate the economic costs for the post-cleanup period. With either alternative these costs would be approximately equal since both cleanup efforts would be concentrated in the same areas with approximately the same results.

This confirms the original assumption that time is the most critical variable in cleaning the PCB's. If it is less expensive to use the bioremediation process in 10 years, does this mean that this is the most economically sound choice for our society? Yes, if we are dealing directly with future costs at specifically that point in time (10 years in the future). However, we are not 10 years in the future and we have the power to prevent 5 or more years of avoidable economic costs. Whichever method can be implemented in the quickest fashion is the method which will be the best economic choice. In the end it is not a question of which process is the least expensive to enact, but one of minimizing the social costs of PCB's in the Hudson River.

PART FIVE
THE FUTURE

FUTURE CONSIDERATIONS

The PCB contamination of the Hudson River will not disappear overnight. Any method that is chosen to rehabilitate the river will more than likely have either environmental or economic drawbacks. These obstacles need to be overcome in order for the Hudson to be the thriving freshwater resource that it has the potential to be. A solution may not always be clear, as shown with the examples of dredging and bioremediation. However, there is an inherent time limit that we must heed to prevent further environmental destruction and economic costs.

As we have seen with the dredging process, there are serious environmental consequences of removing the PCB's and placing them in landfills. Is it safe to encapsulate the toxins on land? The environmental group Citizen Environmentalists Against Sludge Encapsulation (CEASE) says it is not. They feel it is just as unsafe to encapsulate the PCB's on land as it is to leave them in the river. (74) Although the DEC has chosen a site that would fulfill safety standards, some residents in the area are afraid that PCB's may leak into their ground water, causing irreparable damages. (75) And besides, who wants a toxic waste dump in their backyard?

CEASE has joined forces with GE in opposing the dredging project, (76) however the bioremediation process has some consequences of its own. Theoretically the PCB's would be either destroyed or altered, depending on which biodegradation process is used. However, the uncertainty associated with the viability of the program is overwhelming. This, combined with an indefinite waiting period for the process to be reviewed and implemented leads to a large economic risk.

As mentioned in the Introduction, time is not only a factor for economic costs continually borne by society, but it is also a question of the ability to clean up the PCB's at all. Can we take the chance of waiting for approval on various programs knowing that a potential flood or water rising could sweep the PCB's out of reach? It has already been surmised that higher water levels lead to higher levels of PCB's in fish flesh. What then would be the economic damages?

There is no way of knowing what Nature has planned for the Hudson River. Potentially the PCB's could be shifted. Additionally, every year that passes is another year of economic losses. The logical choice, involved is to eliminate the social costs and environmental damage in the quickest manner possible.

Bioremediation may be a process that will remove the PCB's permanently. However, the approval period alone of obtaining permits, having the process examined etc., may take an enormous amount of time. This is time the river may not have. Therefore, the dredging process, with its drawbacks, is possibly the best alternative for immediate action.

The economic costs to society are continuing, as are the environmental consequences of PCB's. It is in the best interest of the state to act and to act quickly. This may mean looking elsewhere for funding, as Superfund approval is restricting potential cleanup, but the state is already bearing the cost for no action. Cleaning the Hudson River of PCB's can only mean economic and environmental recovery, which in the long run will be a less burdensome cost to bear.

CONCLUSION

In conclusion, it is hoped that the original objective, as stated in the Introduction, has been impressed upon the reader. This paper was conceived in response to the writer's desire to relay the severity of the regional problem of PCB pollution which takes its toll on many phases of society. As pointed out in the body of the thesis, the harmful effects resulting from PCB emissions place a heavy burden on the lives and well-being of our citizenry and, subsequently, on our economic viability as well. The environmental future of the Hudson and the future of those economies it affects are dependent upon the actions we take today. Therefore, the writer will attempt to reiterate some of the more salient points previously mentioned while setting a regional picture with the options available at this point in time.

A cost-benefit analysis was intended to be the methodology employed in illustrating the regional problem PCB pollution and control. However, as stated, this methodology suffers from severe limitations at this stage in development due to inadequate data and uncertainty in many critical variables and relationships. Such areas as the effects of PCB's on the Hudson River environment, the effectiveness of proposed programs and economic outcomes for industries must be further refined and depicted on a relative basis. Nevertheless, given the limitations inherent in the data, a few points do emerge which merit validity within the parameters of the study described. By assessing in approximate terms the respective costs and benefits for various alternative strategies, the methodology can indicate where, on the basis of the limited information available, stringent control is desirable. In addition, the cost-benefit study explored has underscored the importance of pollution control. Whether the costs be distributed on an industry basis or a consumer-level, they must be borne.

Many alternatives have been suggested to rehabilitate PCB's in the Hudson. For example the DEC favor the method of dredging. It is asserted that dredging lower the PCB levels in the river by 20% and that this project has important, historical experiences as guidelines. (77, 78) However, spokemen from GE and some environmental groups (CEASE) argue that this does not solve the problem of PCB pollution but only moves it to another location. (79) They feel that bioremediation would be the best alternative with a lower cost and complete elimination or detoxification of the PCB's. (80)

Both alternatives are faced with time constraints - those imposed by the economy and by the environment. Considering the scope of this thesis, time is crucial factor whose relevence must be valued. Indefinite suspension of cleanup mandates indefinite social, economic and environmental costs.

Regardless of which method is ultimately employed a decision to rehabilitate the river implies a value judgment on the cost of pollution. Once the value has been assessed either implicitly or explicitly, it also involves a judgment as to the method to use to motivate private parties to act in the public interest and assume the costs of pollution abatement. (81) When the public interest is at variance with the objectives of a private party, two courses of action may provide sufficient motivation to alter his behavior. His decision may:

(1) be limited by regulations or standards imposed on him by public authority; (2) his values may be shifted toward the overall values of the society by economic means: incentives, taxes, penalties, fees: or by non-economic means such as persuasion that his action will gain him good...The use of economic incentives has been advocated by

virtually every economist who has written on pollution, but has rarely been used as a way of controlling emissions. (82)

However, the PCB's that have polluted the Hudson River are no longer in production, therefore, economic incentives to abate their emissions are no longer possible. We must, therefore, rely on economic penalties and fees to persuade GE to pay for rehabilitation. There are strong suggestions that the benefits of reducing the PCB levels in the river would be substantial and that rehabilitation costs would be, therefore, justifiable.

This is an issue that no longer concerns only a select few. Environmental concerns in the Hudson effect many consumers and industries not directly related to the Hudson River. There are staggering economic ramifications as well as ethical questions that must be answered. Beyond purely the economic impacts of PCB's lies the question of our right to endanger aquatic life and natural resources. Is it acceptable to pollute and emit toxins into our waters as long as we are not hurt by it? Does this earth and environment exist solely for our benefit?

Until a time when we have the answers to these questions it may be wise to remember words written by Ralph Waldo Emerson in Nature, (1836).

"The charming landscape which I saw this morning, is undubitaly made up of some twenty or thirty farms. Miller owns this field, Locke that, and Manning the woodland beyond. But none of them owns the landscape. There is a property in the horizon which no man has but he whose eye can integrate all the parts, that is, the poet. This is the best part of these men's farms, yet to this their land deeds give them no title."

ENDNOTES

1 Boyle, Robert **The Hudson River A Natural and Unnatural History**, (New York, WW Norton & Co., Inc., 1974) Pg 287.

2 Sanders, John E., **The PCB--Pollution Problem in the Upper Hudson River From Environmental Disaster to "Environmental Gridlock", a report prepared for the New York State Department of Environmental Conservation** (1988) p. 1.

3 Ibid., p. 3.

4 Bryant, Nelson: "New York State Seeks Commercial Fishery for Striped Bass", **New York Times**, l3 November 1988, sec. B.

5 Ibid.

6 Sanders, John E., op. cit. p. 17.

7 Ibid. , p .40.

8 Varian, Hal R., **Intermediate Microeconomics: A modern approach**. (New York, W.W. Norton & Co., Inc. 1987) p. 456.

9 Shupp, Bruce D., **Prepared Testimony for the State of New York Department of Environmental Conservation and Industrial Hazardous Waste Facility Siting Board, In Matter of Application of the PCB Project Group for Approvals of the Hudson River PCB Reclamation/Demonstration Project**. 6/30/87, p. 8.

10 "New York State Seeks Commercial Fishery for Striped Bass", op. cit.

11 Bruce Shupp, op. cit., p. 1O.

12 "Cleaner is not Clean" , **The economist** 14 July 1990, p. 31 .

13 "Caution: Contains PCB's". **Electrical World**, February 1983, p. 71.

14 Ibid.

15 Severo, Richard, " New Plan to Dredge Hudson for PCB's Draws Fire", **New York Times**, 21 October 1988, p. B1.

16 "Cleaner is Not Clean", op. cit.

17 Sanders, John E., op. cit., p. 11.

18 Ibid., p. 14.

19 Strom, Steiner, **Environmnetal Economics and management: Pollution and Natural Resources**. (London, Croom Helm, 1988), p. 224.

20 Bridget Barclay, Environmental Director, Hudson River Sloop Clearwater, personal interview, December 14, 1990.

21 Ibid.

22 Sanders, John E. , op. cit. , p. 8.

23 Ibid., p. 12.

24 Bridget Barclay, op. cit.

25 Bruce Schupp, op. cit.

26 Bridget Barclay, op. cit.

27 "Cleaner Is Not Clean", op. cit., p.31.

28 Daniel Abrahamawitz PhD. Biomediation Director, General Electric Company, telephone interview, April 13, 1991.

29 Ibid.

30 Ibid.

31 Ibid.

32 Ibid.

33 Ibid.

34 Ibid.

35 "Cleaner Is Not Clean", op. cit., p.31.

36 Bruce Schupp, op. cit. p. 5.

37 "Cleaner Is Not Clean", op. cit., p.31.

38 Ibid., p. 9.

39 Gold, Allan R., "Hudsons Toxic Striped Bass Disrupt the Season for Shad", **New York Times**, 2 May 1990, p. A1

40 Bruce Schupp, op. cit., p. 8.

41 Ibid. , p. 5.

42 Ibid.. p. 8.

43 Ibid. p. 8.

44 Ibid. , p. l6.

45 Ibid. , p. 17

46 Ibid. , p. 13.

47 Ibid. , p. 13.

48 Ibid. , p. 12.

49 Ibid. , p. 11.

50 Ibid. o p, 12.

51 Ibid. , p. 12.

52 Ibid., p. 15.

53 Ibid., p. 14.

54 Ibid., p. 15.

55 Ibid., p. 15.

56 Ibid., p. 18.

57 Daniel Abrahamawitz, PhD., op. cit.

58 Ibid.

59 Ibid.

60 Faber, Harold. "hudson River PCB Dredging Is Seen as Damaging Farms", **New York Times**, 16 August 1987.

61 Ibid.

62 Daniel Abrahamawitz, op. cit.

63 Ibid.

64 "Caution: Contains PCB's", op. cit., p. 71.

65 **The Environment: a Mission for the Seventies**, (New York, Harper & Row, l977), p. 77.

66 "Caution: Contains PCB's", op. cit., p. 5.

67 Ibid.

68 Bridget Barclay, op. cit.

69 Daniel Abrahamwitz, op. cit.

70 Bruce Schupp, op. cit.

71 Daniel Abrahamwitz, op. cit.

72 Peter Lanahan, Environmental Liason, General Electric Company, New York, telephone interview, April 17, 1991.

73 Sanders, John E. , op. cit. p. 23.

74 Faber, Harold, "Cost to Clean Up PCB's in Hudson Is Rising." **New York Times**, 24 May 1987, p. 30.

75 Ibid.

76 Gold, Allan R., "After 15 Yearg, Hudson Still has PCB's" , **New York Times**, 18 May 1890, p. B1

77 Bruce Schupp, op. cit., p. 5.

78 Sanders, John E., op. cit. , p. 12.

79 "After 15 Years, Hudson Still has PCB's", op. cit.

80 Ibid.

81 Commission on Natural Resources. National Academy of Sciences, National Academy of Engineering and National Research Council Cooperating, Air Quality and Stationary Sounce Emission Control, **Social Research Report**, Ns. 135 (Washington D.C. Government Printing Office, 1975). p. 567.

82 Ibid., p. 548.

SELECTED BIBLIOGRAPHY

Abrahamawitz, Daniel, PHD, Bioremediation Director, General Electric Company, telephone interview, 13 April 1991.

Angiello, Nancy, "The Hudson: Though PCB's Still Taint the Fish, the Water's Getting Cleaner", **New York**, 16 April 1990, p. 36.

"Bacteria May Be Weapon In the Battle Against PCB's", **New York Times**, 8 November 1988, p. Al3.

Barclay, Bridget, Environmental Director, Hudson River Sloop Clearwater, personal interview, 14 December 1990.

Bopp, Richard, "Dating Our Sins", **Natural History**, May 1990, pp. 48-53.

Boyle, Robert, **The Hudson River: A Natural and Unnatural History**, New York; WW Norton & Company, Inc.; 1974.

Brown, Mark P., "Technical Comments: PCB Dechlorination in the Hudson River Sediment", **Science**, Volume 240, 17 June 1988, pp. 1974-1976.

Bryant, Nelson, "New York State Seeks Commercial Fishery for Striped Bass", **New York Times**, 13 November 1988, p. 36.

"Cleaner Is Not Clean", **The Economist**, 14 July 1990, pp. 30-31.

Commission on Natural Resources. National Academy of Sciences, National Academy of Engineering and National Research Council Co-operating. Air Quality and Stationary Sources Emission Control. **Social Research Report** No. 135. Washington, D.C.: Government Printing Office, 1975.

"Cuomo Vetoes Delay in Dredging of PCB's", **New York Times**, 8 June 1990, p. B1.

Downing, Paul B., **Environmental Economic and Policy**, Little Brown and Company, 1984.

The Environment: A National Mission for the Seventies, New York: Harper and Row, 1970.

Essman, Janet, "Behind the Regulations: Fish Flesh and Water Quality", **The Conservationist**, May-June, 1990, pp. 16-19.

Faber, Harold, "Cost to Clean Up PCB's in Hudson Is Rising", **New York Times**, 24 May 1987, p. 30.

Faber, Harold, "Hudson River PCB Dredging Is Seen as Damaging Farms", **New York Times**, 16 August 1987, p. B4.

Faber, Harold, "Inquiry Begins Into PCB Link to Three Deaths", **New York Times**, 16 March 1987, p. B8.

Faber, Harold, "New York Expands Plan to Rid Hudson of PCB's", **New York Times** 21 December 1989, p. B2.

Faber, Harold, "State Panel Named to Review a Proposed PCB Buriel Site", **New York Times**, 21 February 1987, p. BIO.

Gold, Allan R., "After 15 Years, Hudson Still Has PCB's", **New York Times**, 16 May 1990, p. B1.

Gold, Allan R., "Hudson's Toxic Striped Bass Disrupt the Season for Shad", **New York Times**, 2 May 1990, p. Al.

Gutis, Philip S., "Hudson PCB Removal Stalled Again", **New York Times**, 16 January 1986, p. A3.

"Inventory of Toxins Discharged In to Hudson", Environment, October 1985, p. 24.

Katauskus, Ted, "PCB's Fall Prey to Ravenous Bugs", **R&D Magazine**, January 1990, pp. 19-20.

Lanahan, Peter, Environmental Liason, General Electric Company, New York, telephone interview, 17 April 1991.

MacKerron, Conrad, "EPA Sets Cleanup Rules", **Chemical Week**, 8 April 1987, pp. 10-11.

McGraw, Michael G., "The PCB Problem: Separating Fact From Fiction", **Electrical World**, February 1983, pp. 49-72.

Morgon, Thomas, "Court Allows Fisherman's Suit on PCB's in Hudson", **New York Times**, 20 March 1989, p. A5.

Roberts, Leslie, "Discovering Microbes with a Taste for PCB's", **Research News**, 28 August 1987, pp. 975-977.

Sanders, John E., "The PCB-Pollution Problem in the Upper Hudson River: From Environmental Disaster to Environmental Gridlock"; **A report prepared for the New York State Department of Environmental Conservation**; 1989.

Schupp, Bruce D., **Prepared Testimony for State of New York Department of Environmental Conservation and Industrial Hazardous Waste Facility Siting Board, In the Matter of Application of the PCB Project Group for Approvals of the Hudson River PCB Reclamation/Demonstration Project**, 30 June 1987.

Severo, Richard, "New York Plan to Dredge Hudson for PCB's Draws Fire", **New York Times**, 21 October 1988, pp. B1, B4.

Strom, Steiner, **Environmental Economics and Management: Pollution and Natural Resources**, London, Croom Helm, 1988.

"'Super Oxygen' Eases Environmental Problem", **Wall Street Journal**, 2 September 1988, p. B1.

Tietenberg, Tom, **Environmental and Natural Resources Economics**, Glenview, Illinois; Scott, Foresman and Company; 1984.

Varlan, Hal R., **Intermediate Microeconomic: A Modern Approach**, New York, W.W. Norton & Co., Inc., 1987.