WATER POLLUTION TRADING SYSTEMS
FOR IMPROVED RIVER WATER QUALITY :
The Case of Unlike Pollutants

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I. Some History of Pollutant Trading.

There is a long history of interest in pollution trading systems, going back at least to Dales’ interest in air pollution systems (Dales, 1960). Naturally, the interest arises from the objective of cost minimization which, in the simplest case, requires equal marginal costs of abatement across polluters. Trading is motivated by inequalities between marginal abatement costs and the market price of pollution permits which open up the possibility of arbitrage between the two.

Nearly all the systems that have either been operational or investigated theoretically have been for the trading of the same pollutant, e.g. BOD for BOD, SO2 for SO2, nitrogen for nitrogen, etc. One of the earliest cases was the attempt to set up a BOD trading system on the Fox and Wisconsin Rivers in the State of Wisconsin (references later). In this case, it was anticipated that trades would take place among the paper mills that were heavily polluting the rivers and, perhaps, with towns. As has been well noted in the literature (references), the system failed to motivate trades for several reasons : (1) the abatement cost structures of the various plants were very similar ; (2) the system was imposed on top of an already tight regulatory program that had both reduced effluent levels and that introduced uncertainties concerning the consistency of trades with existing regulations; and(3) the companies were not Truly operating “at arms length” from each other since the smaller mills were dependent upon The larger mills for orders.

A second oft-cited case is the Lake Dillon phosphate trading program in which the cleaning up of non-point sources was to be traded against larger allowable loads at local sewage treatment plants—a point versus non-point trading system. It was required that non-point sources such as septic tanks be cleaned up 2 pounds for each added pound of allowable
phosphorous at the treatment plants to allow for the uncertainty of the extent of the non-point cleanup.

The Los Angeles “offset“ program required new sources of air pollutants, especially hydrocarbons, to « buy off » existing sources of the same pollutants in the amount of 120% of the anticipated new load in order to move the Los Angeles air basin towards the existing ambient air quality standards (references). Just how these complicated trades are to be monitored has never been very clear, although it is claimed (reference) that the system has resulted in improved air quality.

The State of Maryland proposed a system of air-borne particulate matter trading that had the unique (and desirable) attribute of recognizing different locations of the sources. Several areas were identified in the State from which sources imposed different depositions on sensitive areas. « Exchange rates » were defined among the areas that allowed trades but made it possible to reach the desired ambient air quality standards. The status of this system is not known to the authors at this moment (references).

By far the best known “like pollutant” trading system has been the U.S. SO2 trading program initiated by the Clean Air Act of 1990. That program involves about 130 large fossil-fueled electric generating plants in the eastern United States. These plants were required to reduce their emissions of SO2 by 50% from their baseline emissions during the 1985 to 1987 period, each plant receiving tradable permits worth 1 ton each in the amount of their allowed emissions. Trading takes place through bilateral negotiations primarily, although the Chicago Board of Trade holds an annual auction for shares that have been withheld by the EPA from issuance or that are offered by individual plants. No locational distinctions are made among the permits and they can be used by any of the electric plants involved. Since the major underlying problem has been acid deposition in upper New York State and in southeastern Canada, it is clear that the primary sources of SO2 (and hence sulfate deposition) are the large plants of the Ohio River Valley that were built soon after World War II without abatement equipment and which burn high sulfur coal from the eastern coal mining states of West Virginia, Pennsylvania and Kentucky. Naturally, in any economically efficient program, these plants should have especially strict trading rules imposed on them, so that a trade would have to result in large reductions elsewhere to increase pollution in the Ohio Valley. Unfortunately, political reality intervened, and the absence of differential trading rules was imposed as a condition of political approval. Robert Hahn of the American Enterprise Institute estimates that this program has saved five billion dollars in abatement costs, but this does not allow for the increased environmental damages caused by sales of permits to plants in the Ohio Valley.

Each of the systems mentioned above involved « like pollutant » trading. There have been some « trading » systems that could be called « unlike pollutant » trading systems. The biggest operational system of this type is represented by the wetlands mitigation program allowed under Section 404 of the Clean Water Act (reference, correct ?). While the filling of wetlands is generally prohibited, under some circumstances the party proposing to fill some wetland area can « make up » for the loss by extending wetland area either in the same wetland system or in nearby wetlands. The issue here is to strike equivalences between one wetland area and another. Each area has many dimensions, and the replacement area is unlikely to have the exact characteristics of the filled area. How can equivalences be established? In fact, the « Delphi method » has been used, with a committee of « gurus » basing equivalences on their expert biological or ecological knowledge of some dimensions of the two areas. No formal rules have been established (references).

Another example that could be thought of as « trading of unlike pollutants » is the program of New York City to clean up its watershed in lieu of having to filter its water supply (references). Since the clarity of the raw water entering the City system has historically been
high, the City has never engaged in filtering the water-only chlorinating it. The EPA has required the City either to build filtration plants (at a cost of several billion dollars) or to take other steps to reduce suspended matter. The City has undertaken a program of working with the towns and individual dairy farms in the watershed to reduce polluted runoff through changes in land use patterns, drainage and treatment systems, etc. Whether or not this program will suffice in the long run is not yet known.

II. The Case of the « Orphan Mine »

The western United States is filled with abandoned mines from activities of the 19th Century when there were no environmental regulations. Many of these abandoned mines are found in the Rocky Mountain region in the headwater areas of many streams. It is estimated that over 3000 miles of streams are currently significantly polluted by runoff from these mines (reference). The runoff usually occurs after periods of heavy rainfall or in the Spring when the snowmelt fills the mines with water. Typically, this water becomes acidic through its contact with sulfur in the rock layers, then dissolving heavy metals and other toxic materials such as arsenic. (references). The effects are much like those experienced in Scandinavia where the sulfate deposition builds in the winter snows, leading to highly polluted runoff during snowmelt.

The particular instance of “orphan mines” that prompted this study is found in the Clear Creek Basin of Colorado, USA, just to the north and west of Denver as shown in Figure 1.

The lower part of the Clear Creek watershed houses the town of Golden (home of the Colorado School of Mines) and the Coors Brewery which share a waste water treatment plant emptying into Clear Creek. Coors Brewery has the distinction of being the world’s largest single brewery plant (though there are larger companies having multiple plants). The entire production process is carried out in copper equipment-pipes, vats, etc. Thus the waste water stream carries a large concentration of dissolved copper (amount?). The effluent limits set by the U.S. EPA are raised every 5 years, and Coors was faced with the need substantially to reduce its copper output. Since the treatment plant already incorporated advanced technologies, the next step of clean up of the dissolved copper was going to be extremely expensive. The Company proposed to clean up one or more abandoned mines in lieu of having to drastically reduce its output of dissolved copper.

The idea seemed to be of even broader application and interest since there are many abandoned mines and since ambient water quality has become a limiting factor in various parts of the Clear Creek watershed. Other parties, e.g. real estate developers, industrial plants, towns in the watershed facing the Coors type of problem became interested in similar possibilities. The private Non-Point Source Council (proper title?) agreed to fund a study concerned with how a trading system could be established that would continue to meet existing ambient quality standards and, in fact, improve “stream quality” or “stream health” over time, while saving polluters substantial sums.

However, the trading of a “basketfull” of cleaned-up pollutants for an increase in one or more pollutants elsewhere in the system is a complex process. To what extent can unlike pollutants be exchanged without degrading “stream health”? U.S. water quality regulations do not allow further stream degradation (reference to relevant law), but it is clear that the trading of unlike pollutants must result in increased emissions of pollutants somewhere in the system,
e.g. just below the expanded source, although this hopefully would not violate the ambient standards for the stream.

Unlike pollutant trading involves three major types of “unlikeness” or lack of similarity:

1. “out-of-kind” trades, i.e. those that involve different pollutants;
2. “out-of-place” trades that involve clean-up at one location but expanded output of pollutants at another;
3. “out-of-time” trades that involve different time patterns of cleanup and pollutant output.

The first complexity is simply the large number of pollutants involved in water quality, any one of which can be damaging if present is too great concentration. The elements of concern in the Clear Creek setting are shown in Figure 2.

It turns out that very little is known about the effects of these elements on what might be called “stream health” when the elements are present in concentrations below the critical level where obvious damage is being done to the riverine ecosystem. Therefore, the field of stream biology has little to tell us about the value of unlike trade-offs in improving stream health.

“Out-of-place” trades obviously mean that some “reach(s)” of the river will improve in water quality, while others will be degraded, e.g. just below the cleaned-up site and just below the new source. In some cases, many reaches of the stream will be affected while in others only one reach may be involved. How should the effects on different parts of the stream be weighted?

“Out-of-time” dimensions of trades pose difficult problems of evaluation. In the case of old mines, the discharges of pollutants can be quite episodic because they are caused by rainfall and snowmelt that infiltrate the mined spaces, dissolving heavy metals and other damaging pollutants in the process. Illustrative data are given in Figures 3 and 4.

On the other hand, the expanded source of pollutants, usually being a human-controlled process, is likely to have a much more uniform pattern of discharge. How are such different time patterns to be exchanged against each other? Naturally, it is widely recognized that peak and not average concentrations of pollutants are likely to be the most important dimension for stream health.

The objectives of our study, then, were to develop a design for unlike pollutant trading that would accomplish the following:

1. motivate mine clean-ups through the generation of profits and/or cost savings;
2. result in improvements in “stream health”;
3. be consistent with existing water quality regulations and institutional responsibilities;
4. involve a large number of market participants, e.g. towns, industries, agencies of government, environmental groups, etc.

III. Designing the Unlike Pollutant Trading System.
A. Steps in the Evaluation and Approval of a Trade

Table 1 below lists the steps that are necessary to the evaluation and potential approval of unlike trades.

The first step is to predict the effects of the clean-up in terms of the reduced emissions and their time patterns. This is not a simple feat since the efficacy of the clean-up is accompanied by considerable uncertainty, especially given the complex geology of mining regions. Will it be possible to stop flows altogether or will some flows remain? Will containment be effective or only under certain conditions? Will a treatment plant be necessary? Will the clean-up be permanent or will its effectiveness deteriorate over time? Naturally, an entrepreneur could proceed to clean up the old source to find out through experience what the reduction in pollutants would be, but this could involve great expense based on quite unknown results. Even then, the permanency of the clean-up may be in question since geological or unrelated hydrological shifts may take place.

The pollution loading of the proposed new source is likely to be more predictable. If it is an industrial process, the chemistry is likely to be highly predictable as are the results of waste water treatment processes. If residential or recreational activities are involved, the resulting waste loads are pretty well known from experience.

The third step is to model the effects of the clean-up and new source on all affected stream reaches. Naturally, this can push water quality modeling to its limits, since multiple pollutants are involved, among which there can be synergistic effects, e.g. among nitrogen, phosphorous, and dissolved oxygen (see Howe and Carmichael, 1998).

The fourth step is the most interesting and the most challenging: to devise rules for determining which trades are allowable under the objectives noted above, e.g. improving stream health and remaining within existing water quality regulations while motivating clean-ups. Naturally, proposed trades must meet these rules, and both the clean-up and the new source must then be monitored on a continuing basis.

B. Approaches to the Evaluation of Trades.

The ideal solution to evaluating trades would be to have our colleagues in stream biology provide us with an “index of stream health (or stream quality)” that would take the form given in equation 1:

$$Ho = F(x_1, x_2, \ldots, x_{k1}; \ldots, z_1, z_2, \ldots, Z_{kn})$$

where the variables represent all the pollution concentrations (and other physical conditions) in all reaches of the stream. Not surprisingly, such a function is still far out of reach, both for a dearth of biological knowledge and because it requires some kind of weighting across the various reaches of the stream-a matter for economists and politicians.

We have undertaken what we have chosen to call “the target zone approach”. The target zone for a particular pollutant in a particular reach of the stream is a range of ambient concentrations starting at zero and ranging up to the currently applicable water quality standard for that pollutant in a river of given classification (rivers according to primary use may have different standards). A pictorial display of the target zones for relevant pollutants (and physical conditions) is shown in Figure 5 below.
The display is somewhat deceiving since the length of each target zone is pictured of the same length when they represent, in fact, quite different ranges of ambient concentrations. Concentrations that violate the standards are shown as black extensions to the right of the target zones. The idea is to encourage clean-ups that bring the non-complying pollutants within their target zones and to allow increases in pollutants that are within their target zones. While many rules can be imagined that would encourage such actions, we have chosen the following rule:

RULE: NO TRADE CAN CAUSE ANY POLLUTANT CONCENTRATION (OR PHYSICAL CONDITION) IN ANY REACH OF THE STREAM TO (1) EXCEED THE TARGET ZONE LIMIT NOR TO (2) INCREASE THE AMBIENT CONCENTRATION OF ANY POLLUTANT IF ALREADY OUTSIDE THE TARGET ZONE.

Case 1 illustrates a typical “orphan mine” situation in which an upstream source is cleaned up in return for an increase in in emissions further down on the stream. Stream “reach” 4 is brought into compliance with ambient standards with the clean-up. This results in ambient improvements in reach 5, bringing it also into conformity. The available room or “freeboard” now available in R5 could be used to accommodate the new source. Naturally, more stringent trading rules might permit only some part of the “freeboard” to be used by the new source.

Case 2 illustrates a situation that is actually under consideration. The Little Bear Mine lies in the drainage of Soda Creek which is now heavily polluted by the runoff from the mine. The clean-up results in improvements in the ambient concentrations of both pollutants in R 1. This naturally benefits R 4 and R 5. The proposed new source is a housing development on R 1 (Fall River) which, even after the required treatment, would lead to increased concentrations of both pollutants in R 1 which will adversely affect R 3, R 4 and R 5. R 3 is in Compliance with the existing standards before the housing development but would be forced out of compliance with pollutant A after the development. R 3 is, therefore, according to our rule disallowing the new development. R 4 and R 5 could also be limiting.

The actual estimated data on the Little Bear clean-up and its effect on Soda Creek are shown in Table 2 and Figure 8.

IV. Institutional Issues.

We will not dwell on the institutional issues because they are so specific to each country or even to different regions within a country. In the “orphan mine” case, the responsibility for carrying out the steps described above needs to be assigned to some entity that has the required technical capabilities. This could be an existing agency related to water quality management (e.g. the Department of Health’s Water quality
Control Division in Colorado) or a new entity specifically designed to encourage and evaluate trades. The latter might be called a “basin water bank” which would be responsible for evaluating and approving trades, along with the needed “bookkeeping” to keep track of all transactions.

Such an entity starts within a complicated framework of other agencies that have responsibilities within the basin. In the case of Clear Creek, Colorado, this set of agencies would include the U.S. EPA with its nationwide responsibilities for the setting of minimum stream standards; the State Department of Health that is required to have a “state implementation plan” that links effluent permits to the required ambient standards; the State Department of Natural Resources that administers the system of water rights; the U.S. Forest Service that controls a large portion of the land that is not privately owned in the basin; the U.S. Bureau of Land Management that controls other lands in the basin; the U.S. Army Corps of Engineers that must approve any modification of wetlands; etc. The trading scheme and the basin water bank administering it ought to have the approval of these agencies. Other types of permits will be required for some trades, e.g. if the mine to be cleaned up is on Forest Service or Bureau of Land Management land.

The administration of water rights may be directly affected by some proposed pollutant trades, especially those in which the temporal pattern of runoff is modified by either the clean-up operation or the new source. This could be beneficial or damaging.

In addition to all the existing agencies that may have a rôle to play, there will be “stakeholder” groups of citizens, businesses, farmers, environmentalists, etc. that can either reinforce or resist the creation of a trading scheme. Public involvement will be required. In the Clear Creek case, “focus groups” were held to plumb public opinion, followed by community informational meetings. No group likes to have surprises on matters of interest.

V. Possibilities for “Banking” Pollution Credits When Clean-up and the New Source Have Different Time Horizons.

There are likely to be cases wherein clean-up precedes the creation of the new source. For example, a real estate developer may be planning a housing development for 5 years from now. The new community, while being required to have a wastewater treatment plant, will add pollutants to the stream that will cause violation of stream standards. The local government that must issue the building permits for the development is not allowed to do so under these circumstances. Ambient water quality is limiting further development in the basin. The developer knows (or hires a consultant engineer) of clean-up opportunities that would bring the stream into compliance post-development. The developer may, therefore, propose a clean-up today to “guarantee” that the development will not be disallowed five years from now. Clearly, it pays to “get into the game early” while there is the widest selection of mines to be selected. Some will be low cost and others high cost. How could the basin water bank handle such proposals?

Clearly, it is desirable to encourage early clean-ups and it is all the better if the use of the possible pollution credits is delayed. The simplest procedure would be one in which the trade would meet the basic rule if both clean-up and source were to occur today. The use of
“freeboard” that will then occur in five years (i.e. the allowed increase of ambient concentrations that are already within their target zones) can be reserved, i.e. treated just as if the new source were occurring today. The drawback would be that there might be other parties that, within the near future, might have proposals to use that “freeboard” earlier.

A second situation might be that environmental interests, including some government agencies, might want to clean up a mine just to improve the water environment. This might be done to improve recreational quality in the basin. Naturally, any agency or group going to the expense of clean-up would not want the “freeboard” thus created to be used up by other polluters who might move in. In this case, the improvements in ambient concentrations might simply be permanently subtracted from the upper limit of the target zone. While this makes sense from the environmental viewpoint, it would surely be fought by many traditional interests.

A third and potentially important situation would be one in which some party with expertise and money to invest would “speculatively” clean up a mine, anticipating that he/she could later sell the “credits” thus earned for a profit. The question would be, of course, “What credits, if any, should be issued in this situation?” It seems desirable from an environmental point of view not to discourage such activities, but the situation differs greatly from that in which a definite new source is being proposed. Clearly, the entrepreneur should not be issued all available “freeboards.” One approach would be to “reserve” for him/her the improvements in freeboards created by the clean-up. This probably should be for a specified period of time, say 5 or 10 years. As the assimilative capacity of the stream becomes more fully utilized, these freeboards should become more valuable, providing the motivation for such speculative clean-ups.

VI. Conclusions.

There are many abandoned toxic sites around the World. Many impose high human and environmental costs, but responsibility often cannot be fixed. One solution would be to have some level of government carry out the clean-up, but that would tax both the budgets and the expertise of government. The issue then is to provide motivation for interested parties to undertake these clean-ups when it is economically efficient to do so. Given currently existing water quality programs in most of the World, water quality is frequently a limiting factor on further economic and demographic growth. This suggests that new activities that would impose additional pollution on the stream could undertake the clean-up of toxic sites while being allowed to use some of the “freeboards” (reductions of ambient concentration levels below present standards) thereby created.

It appears that economic efficiency would be well served by such activities. The new source would seek the minimum cost way of fitting into the current standards, either through internal methods or by cleaning up other sites. In many cases, cleaning up abandoned toxic sites would be the lower cost of the two. Among the possible clean-ups, they would seek the lower cost opportunities that would reduce the various pollutants sufficiently to “fit into” the regulatory system in accordance with the rule we have proposed. In that case, stream quality will increase over time in the sense of moving toward compliance with the existing standards. When standards are not being pressed, the required clean-ups could be small and/or inexpensive. As
further development occurs and as a larger number of ambient standards become binding, required clean-ups will become larger and more costly. But the clean-ups will still frequently be lower in cost than the other methods available to the new sources.

There are many institutional issues to be solved—issues that will be unique to each basin. A new agency or “water bank” might be needed, but the administration of the system could be given to an existing agency. This might be the better choice, since the program of toxic site clean-up will have a finite life. When clean-ups rise in cost to the level of alternative methods for avoiding breach of the standards, the program is likely to end. When costs of meeting standards in one basin rise above those of other basins, development will slow or stop.

The system proposed above clearly is only as good as the existing set of standards. If the ambient standards don’t make sense, then we will have only a system that minimizes the cost of reaching the wrong objectives. Since, however, the use of systems of ambient standards has been accepted around the world, the proposed system for the trading of unlike pollutants makes economic sense. As more is learned about the chemistry of riverine ecosystems, standards will be adjusted accordingly. Some day we may be able to take the approach of judging proposed trades on the basis of a super index of “stream health”. Until then, the “target zone” approach warrants consideration for many basins.