THE FEASIBILITY OF MODELING THE FATE OF ORGANICS AND HEAVY METALS IN THE YAMASKA RIVER WATERSHED BEFORE AND AFTER THE CONSTRUCTION OF A CAR ASSEMBLY PLANT NEAR BROMONT, QUEBEC

by
Efraim Halfon

National Water Research Institute
Canada Centre for Inland Waters
Burlington, Ontario, Canada L7R 4A6
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ABSTRACT

The Yamaska River watershed is located in the province of Quebec and its waters enter the St. Lawrence River ecosystem in Lac Saint-Pierre. In the near future the Korean company Hyundai will start building a factory along the shores of the Yamaska-centre River near the Bromont mountain recreation area. The factory is planned to start the assembly of cars by the Spring of 1988 with full production by 1991. The purpose of this feasibility study is to explore the use of mathematical modeling activities to assess the expected impact of the new factory on the Yamaska-centre River and the whole Yamaska River. This impact will take the form of release into the river of 50-100 heavy metals and toxic organics once production starts.

RÉSUMÉ

Le bassin hydrographique de la rivière Yanaska se trouve dans la province de Québec et ses eaux se jettent dans l'écosystème du Saint-Laurent dans le lac St-Pierre. Bientôt, la société koréenne Hyundai entreprendra la construction d'une usine le long des rives de la rivière Yamaska centre, près du centre récréatif de Bromont. L'usine doit commencer à produire des automobiles au printemps 1988 et la production devrait atteindre son sommet en 1991. Cette étude de faisabilité voulait explorer l'utilisation de modèles mathématiques pour l'évaluation de l'impact éventuel de la nouvelle usine sur la zone centrale de la rivière Yamaska et sur l'ensemble de la rivière. Cet impact découlera du rejet dans les eaux de la rivière de 50-100 métaux lourds et matières organiques toxiques une fois la production démarrée.

MANAGEMENT PERSPECTIVE

The Yamaska River is located in Quebec. The Yamaska River supplies drinking water to about 80% of the population living in its watershed. Its water is also used by industry. Hyundai plans to build an assembly plant in Bromont, Quebec. The company expects that the $ 325 million plant will employ 1500 workers by 1991, when production is expected to reach 100,000 cars. With the beginning of production the river will be the recipient of licensed discharges of contaminants, organics and heavy metals. This feasibility study investigates the possibility of using mathematical models to direct data sampling efforts to assess the possible impact of the Hyundai plant on the Yamaska River.

PERSPECTIVE ADMINISTRATIVE

La rivière Yamaska se trouve au Québec. Elle approvisionne en eau potable environ 80 % de la population qui vit dans son bassin hydrographique. Ses eaux sont également utilisées par l'industrie. La société Hyundai prévoit construire une usine d'assemblage de 325 millions de dollars à Bromont au Québec. D'ici 1991, moment où la production doit atteindre 100 000 automobiles, 1 500 personnes devraient être engagées. Au début de la phase de production, la rivière servira de milieu récepteur pour le déversement autorisé de contaminants, de matières organiques et de métaux lourds. Cette étude de faisabilité visait à déterminer la possibilité d'utiliser des modèles mathématiques pour guider les efforts d'échantillonnage en vue d'évaluer l'impact éventuel de l'usine de la société Hyundai sur la rivière Yamaska.

BACKGROUND

In 1984 Dr. R.J. Maguire approached Environment Quebec about the feasibility of sampling the Yamaska River (Figure 1) to assess the presence of dyes and pesticides in its waters. This sampling program took place in the Spring of 1985 and 1986 before the Hyundai company decided to locate its plant there. These data from the river are currently in the laboratory being analyzed.

The Yamaska River is located in an area where the main economy is agricultural; several dairy factories exist near the towns of Granby and St. Hyacinthe. Only a few industries, such as IBM, exist near the town of Farnham. The river is very eutrophic, pig and cattle farms produce large amounts of phosphorus, and several municipalities have applied for funds recently allocated by the Quebec Provincial government for the construction of wastewater treatment plants. Two wastewater treatment plants have already been built in Granby and Waterloo and others are planned. The funding arrangements for this projects imply that the provincial government will provide nine dollars for each dollar raised by the local municipality. Once the wastewater treatment plants are built the operating costs will be the responsibility of the municipalities themselves. The running costs are estimated at one sixth of the capital funds per year. Several plants have been built in Quebec under this project but no data exist to confirm the efficiency of the plants, that is, the percentage of phosphorus removed. These wastewater treatment plants have not been designed to deal with the problem of contaminants. An optimal allocation study of the wastewater treatment plants was conducted at the INRS-Eau by a student of Dr. Villeneuve for his dissertation. The modelling study investigated the optimal location and efficiency of the wastewater treatment plants along the Yamaska River.

This study, scientifically accurate, was considered irrelevant politically and it was dismissed in the Quebec Legislature even if its proposals would have saved the provincial government up to 60%; in fact this optimal allocation study argued for the construction of fewer plants than the municipalities wanted, thus reducing the total amount of provincial funds available locally.

The Yamaska River supplies drinking water to about 80% of the population living in its watershed. Only few communities drink groundwater rather than river water. Sources of pollution to the river, in addition to the organic phosphorus produced by cattle and pig factories, are the large amount of pesticides used by the agricultural industry. Every year the Quebec Bureau of Statistics produces a census with the data of pesticide sales and consumption.

The Yamaska-centre River, located upstream of the main Yamaska River, is still relatively clean compared with the rest of the river which is already heavily polluted. The major source of heavy metals to the Yamaska-centre River might be the nearby highway 10 connecting Montreal with the Eastern Townships and the heavy traffic of cars to the Bromont ski area. Downstream from the proposed location a natural fishery exist; this fishery is locally exploited by local fisherman for recreation.

ENVIRONMENTAL IMPACT ASSESSMENT

Hyundai plans to build an assembly plant in Bromont, Quebec. The company expects that the $ 325 million plant will employ 1500 workers by 1991, when production is expected to reach 100,000 cars.

By law the Hyundai plant must be licensed by the Quebec government following an environmental impact assessment. For this purpose Hyundai has hired a local consulting company to make the necessary measurement requested by Environment Quebec. In this instance the main concern is the expected concentration of a large number of heavy metal and organics in the waters downstream from the plant. This water is a source of drinking water and used by the sport fishery.

Hyundai has provided a partial list of chemicals that might be expected to be released into the environment with an estimate of amounts for each chemical. Environment Quebec is concerned about the future concentrations of these pollutants in the drinking water supply downstream and the expected concentrations in fish. According to Simotte (Environment Quebec, pers. comm. 1987) the overall loadings should not be a hazard to the fishery, a spawning ground, and should not harm the population downstream. The major problem with discharge of pollutants in rivers is that a number of chemicals might not flush directly downstream but some might sediment in different parts of the river to be later resuspended and moved downstream. When this phenomenon, called "spiralling" occurs, the pollution levels downstream might be higher than expected by considering only pure dilution. To analyze the expected effects of pollution on a river ecosystem the following discussion bounds the limits of the problem.

River ecology

In the systems approach rivers are considered spatially heterogeneous systems that maintain their ecological balance over time using control effects. Current ecosystem theory predicts that stream have low resistance to perturbations relative to forests, lakes and oceans (i.e. streams are more easily displaced from a reference state) but have high resiliency (i.e. return rapidly to the reference point when perturbed).

With the seeming lack of resistance and predictability of energy and nutrient resources in streams, the question arises as to what mechanisms are involved in the persistence of stream ecosystems. With the absence of closed recycling loops in streams, one mechanism for controlling nutrient and energy losses via hydrologic transport is through regulation of outflow losses by stream biota. Nutrients and energy are released at one point in a stream become available as resources (i.e. stabilized inputs) at points further down the topographic gradient. Thus, resources are successfully "spiraled" down the stream rather than "recycled" in place. Webster (1975) has introduced the term "spiralling" and suggested that such a mechanism would lead to greater stability than predicted from previous theory. Thus, it can be hypothesized that streams are "spiralling" or cascading systems in which the retention time and efficiency of resources utilization are maximized through control by specialized functional groups down the stream continuum.

Toxic contaminants are also "spiraled" down the stream and their effects might last significantly longer in the stream ecosystem that if they were just transported downstream with the water. As mentioned before, spiralling is a beneficial mechanism in rivers since it helps to maintain an ecological balance in the stream following perturbations but it also helps to increase the damage made by uncontrolled spills of contaminants.

The mathematical model that could be used to simulate the fate of contaminants released by the Hyundai car plant should include spiralling, and uncertainty analysis should analyze the effects of different rates of spiralling on the aquatic communities living in the river.

MODELLING, DATA COLLECTION AND IMPACT ASSESSMENT

Environment Quebec realizes that the car manufacturing plant will heavily impact the Yamaska River ecosystem by releasing toxic contaminants into the river waters. The quantification of this impact might be possible using a holistic systems approach and mathematical models.

The first problem is that no data exist on the Yamaska River near the area where the plant will be located, i.e. no information has yet been collected on the bottom sediments present in the river, their bulk density, organic content, porosity, sediment texture of glacial and modern sediments, and on the dynamics of the suspended sediments such as sedimentation and resuspension rates, and their concentrations during periods or low and high flow. This basic knowledge on the river must be collected to understands the dynamics of the expected contaminants in the river.

Given this lack of knowledge, mathematical models could be used to plan sampling programs in the river, to gather information about the chemicals that will be released in the environment and to predict the fate of these contaminants in different parts of the river and the expected concentrations of contaminants in downstream drinking water supplies and in the sport fishery. The advantage of using mathematical models for planning the sampling program and to assess the environmental impact is that mathematical models describe the assumptions about the ecosystem of interest in a clear and unequivocal way. The equations include information about the river dynamics and the interaction of the physico-chemical properties of the contaminants with the environmental properties of the river. Since models require a certain amount of information as boundary conditions, only information required to run the model should be collected with a savings in sampling costs.

Table 1 shows the information that should be collected in the river and obtained from Hyundai to allow a preliminary evaluation of the expected impact. Some questions that might be important to local communities deriving their drinking water from the river are:

a) how toxic are the contaminants ?

b) what will the concentration profile look like downstream ?

c) where is the nearest drinking water intake ?

d) how long before a spill reaches the water intake ?

The required hydrological data (i.e. discharge at the cross-sectional panel containing the sample intake) can be obtained from either existing hydrologic models adapted to the Yamaska River. Since the major pollution in the Yamaska-centre River will come from this car plant, there is the possibility of very large problems, in the vicinity of the plant, arising from careless, or inadequate design and operations of the plant. The measurements suggested in Table 1 can be used as inputs to the mathematical models to estimate expected concentration levels at different parts of the year. Such data combined with those on environmental factors like physico-chemical, morphometrical and biological characteristics of the water of concern, as well as the toxicant budget (input, partition, output) would yield a matrix that might give a more sound estimate of the (site-specific) ecological impact of a given substance when applied to proper mathematical risk models.

Once these data are available uncertainty analysis can be performed with the model to compute the probability of observing different concentration levels in river water and fish. Since no standards exist for the Yamaska River, the results of these simulations can be used for discussion with Hyundai to agree to maximum concentration of all the contaminants in the river downstream and the expected probability that these limits will be exceeded in a given time period.

No single fate model can be recommended as best for the purpose of sampling design and impact assessment. Hyundai might decide to use any model already available in the literature and mutually acceptable to the company and to Environment Quebec. The consulting company might develop new fate models for organics and heavy metals under supervision of scientists from Environment Quebec and/or Environment Canada. The collection of information should be responsibility of Hyundai and data should be shared with government agencies. If the consulting company can prove expertise in the simulation field or can hire subcontractors, it could run the model uncertainty analysis under supervision of scientists of Environment Canada; otherwise the consulting company could provide funds to Environment Quebec or Environment Canada to have the simulations performed by these organizations.

An impact analysis has to focus on measurable properties and on detectable changes. From an impact point of view two properties should be measured, concentration of toxic contaminants and effects on the biological populations; the Microtox test might be used for this purpose. Mathematical models or back-of-the envelope calculations using linear relations with the octanol-water partition coefficient can also be used to assess whether a given compound would be likely be found in the water compartment or in the suspended and bottom sediments thus directing the monitoring activities to specific compartments. In an ecosystem two kinds of factors are important for a healthy biological community: low mortality rates and viable reproduction rates. A healthy biological community must exist in different part of the river; this community is also important to absorb any man-made perturbations such as unexpected spills.

An ecosystem monitoring strategy would therefore be directed in two directions, one to monitor the water for the presence of toxic contaminants known to be manufactured in the area, and second an analysis of the effects of observed and undetected contaminants with the use of bioassays, such as the Microtox test.

Globally an impact analysis of a river ecosystem can be summarized in the following way:

Evaluation of environmental and human risk of chemical compounds

Risk evaluation of environmental chemicals (Halfon, 1986)

Environmental and human risks = f(exposure + bioactivity) of a chemical compound (by measurement)

Exposure = f(Exposure concentration + duration) (by models)

Exposure concentration = f(Partition Behaviour + Input) (by models and measurements)

Partition Behaviour = f(Sorption/ Bioconcentration Parameters) (by models)

Sorption/Bioconcentration Parameters = f(Molecular structure) (by QSAR studies) + nature of sediment or suspended solids (% organic carbon)

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bioactivity/Toxicity = f(Molecular structure) (by QSAR studies)

Risk evaluation = f(Molecular structure + Exposure duration + Input) (by QSAR, models and measurements).

ROLE OF ENVIRONMENT CANADA

The previous sections of the report have focused on definitions of the river ecosystem concept and the development of research programs to determine the fate and environmental effects of toxic contaminants in the river.

Research programs however are only one of the concerns of Environment Canada, the other major concern is the development of a monitoring program to continually control the state of water quality and to detect any signs of deterioration after the car assembly plant begins operation. Environment Canada basic strategy is to prevent toxic substances from entering the environment and therefore the car manufacturer is required to minimize the amount of toxics released into the river during production. Integral features of this system is testing, monitoring, registration, and where necessary, the development of guidelines and regulations to be consistently enforced.

The expected construction of a car plant in Quebec allows an excellent opportunity to study the the Yamaska River environment before the plant is built, before it begins operation and after the plant is in operation. Since the plant will discharge both organics and heavy metals there is the opportunity of having scientists of both specialties involved in monitoring studies. These studies will also be interesting in a comparative way when other car companies will be locating in Canada, for example Toyota in Cambridge, Ontario. From a funding point of view this effort is also of interest to Environment Canada and Environment Quebec since the consulting company hired by Hyundai would have to perform all the necessary measurements before the plant is built and therefore funds for this research will not all come from the federal and provincial governments.

For modelers this study might provide an important opportunity to use models to direct data collection at specific sites, to establish water quality standards in the Yamaska River, and to assess the forecasting ability of fate models in rivers. For toxic organics Environment Canada might suggest the usage of the model TOXFATE (Halfon, 1986); for heavy metals fate models from the literature might be used. As mentioned above the modeling work might be done under supervision by the contractor or might be done in-house by the provincial or federal government. Since the area near Bromont is expected to be labor-union free, other large factories might be expected to locate in the same area later. Mathematical models might therefore be also used to assess the impact of other new factories located in the same area. Collaboration between government and industry might lead to economic development of the area without disruption of the sport fishery in the river and without hazard to the drinking water supply.

REFERENCES

Halfon, E. 1986. On ranking chemicals for environmental hazard. Environ. Sci. Technol., 20, 1173-1179.

Webster, J.R. 1975. Analysis of potassium and calcium dynamics in stream ecosystems on three Southern Appalachian watersheds of contrasting vegetation. Doctoral thesis, University of Georgia, Athens, Georgia.

Table 1: Data needs.

a) Data that should be collected in the Yamaska River at Bromont, near the fish spawning grounds and near drinking water supplies pipes. These data should be collected several times during the year in periods of low water in winter and summer and during periods of high water flows in spring.

Bottom sediments	suspended sediments	plankton	fish
kind, gravel, sand	concentrations	concentrations	concentrations
bulk density	organic content	organic content	species
organic content			individual weight

b) Data that should be obtained by Hyundai company.

List of all contaminants, metals and organics that will be released.
Relative amounts for each contaminant during periods of maximum production.
Physico-chemical properties of each contaminant.

- Molecular weight
- Water solubility
- Octanol-water partition coefficient, K_{ow} or log P.
- K_{oc}
- Partial vapor pressure
- Henry's Law constant
- Hydrolysis rates at river pH
- Oxidation rate
- Photolysis rate
- Biodegradation rate

c) Other environmental data

- Wind speed at 10 metres over the air-water interface
- Water and air temperature
- River flows
- River topography, slope, mean depth

d) Other contaminant data for contaminants already present in the river.

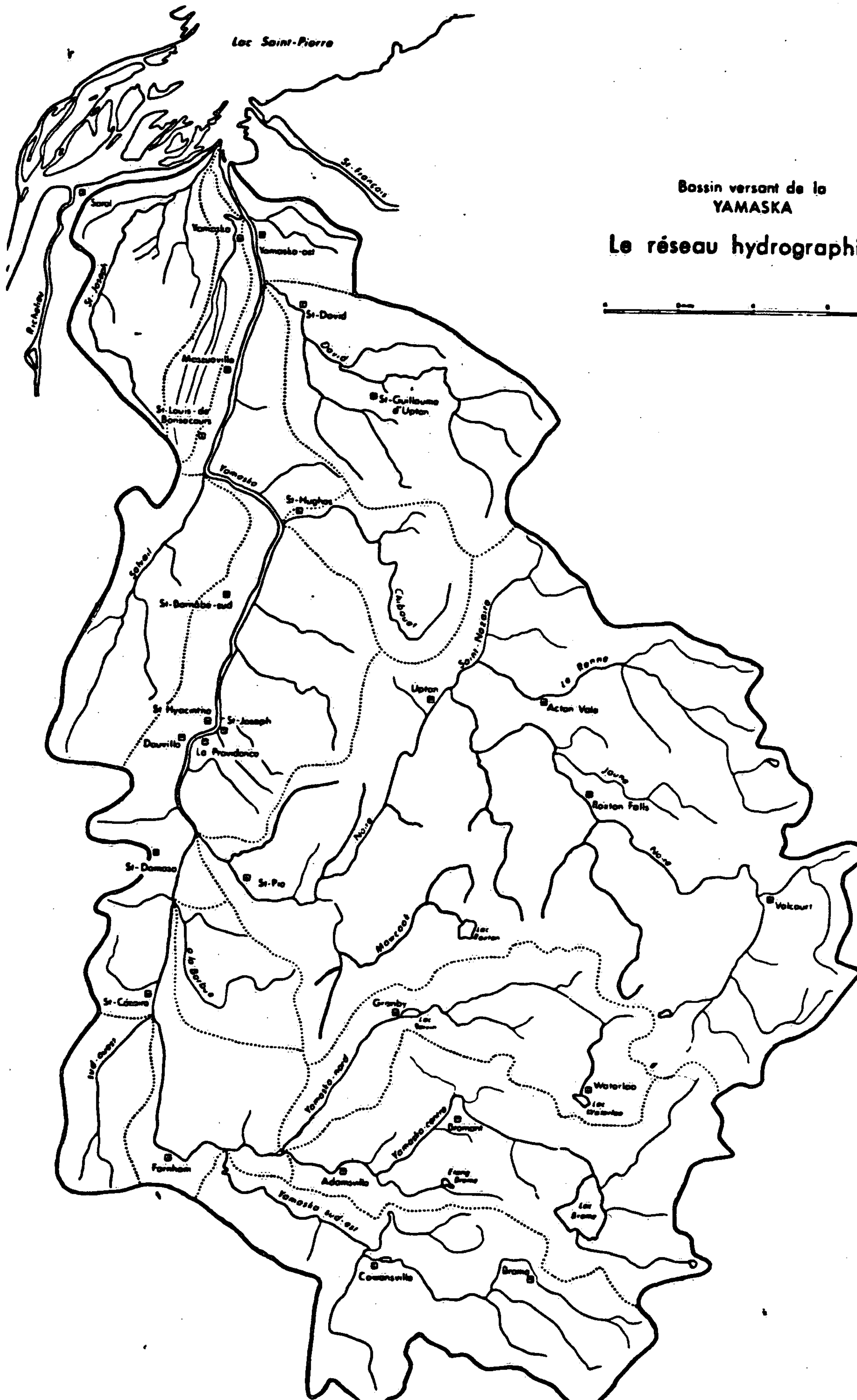
- Measure concentrations of in river waters
- Measure concentrations of in bottom sediments
- Measure concentrations of in suspended sediments
- Measure concentrations of in plankton
- Measure concentrations of in fishery
- Install cages in different parts of the river with fish to estimate uptake and depuration rates now and when plant will be in operation.

e) Toxicity data

- to river communities
- to fish
- to human population

Bassin versant de la YAMASKA

Le réseau hydrographique



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With the seeming lack of resistance and predictability of energy and nutrient resources in streams, the question arises as to what mechanisms are involved in the persistence of stream ecosystems. What mechanisms have evolved, for example, to provide resiliency and stability to their biological structure and function in the face of continuous downstream transport of nutrient and energy resources.

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Bullshit! These are anything but clear! You use the word 'assumptions'.