

PPP 1234
DUKE UNIVERSITY LIBRARY
100 20

JUN 22 1977
3853
DURHAM, N. C.

Journal of the Fisheries Research Board of Canada

Journal de l'office des recherches sur les pêcheries du Canada

Volume 34, No. 6, June 1977

Volume 34, n° 6, juin 1977

Pulp and Paper Mill Effluent in a Freshwater Environment¹

For
Reference

J. R. M. KELSO² AND C. K. MINNS

Department of Fisheries and the Environment, Fisheries and Marine Service, Canada Centre for Inland Waters,
Great Lakes Biolimnology Laboratory, Burlington, Ont. L7R 4A6

AND R. J. P. BROUZES

Domtar Ltd., Domtar Research Centre, Senneville, Que.

KELSO, J. R. M., C. K. MINNS, AND R. J. P. BROUZES. 1977. Pulp and paper mill effluent in a freshwater environment. *J. Fish. Res. Board Can.* 34: 771-775.

Background and scope are provided for joint Ontario Ministry of the Environment and Department of the Environment studies of the effect of a pulp and paper mill effluent in a freshwater ecosystem. Brief descriptions of pertinent features of the pulp and paper mill and Nipigon Bay are given as related to studies presented in this volume.

KELSO, J. R. M., C. K. MINNS, AND R. J. P. BROUZES. 1977. Pulp and paper mill effluent in a freshwater environment. *J. Fish. Res. Board Can.* 34: 771-775.

Cet article sert d'arrière-plan et définit la portée d'études entreprises conjointement par les ministères ontarien et fédéral de l'Environnement sur l'effet de l'effluent d'un moulin de pâges et de papier sur un écosystème d'eau douce. On y présente de brèves descriptions des caractéristiques du moulin de pâte et de papier et de la baie Nipigon pertinentes aux études contenues dans ce numéro.

Received July 5, 1976
Accepted October 6, 1976

Reçu le 5 juillet 1976
Accepté le 6 octobre 1976

The International Joint Commission (IJC), established in 1909 under sanction of the Boundary Waters Treaty Act, is charged, as part of its

responsibilities, with conducting extensive investigations on questions arising between the Canadian and United States governments along their common frontier. Findings complete with recommendations are reported by the IJC to respective governments. Seriously concerned with the deteriorating water quality of the lower Great Lakes

This paper is part of a series concerning the impact of pulp and paper mill wastewater discharges into Lake Superior. This study was carried out in 1974 and 1975 under the auspices of the International Joint Commission, Upper Great Lakes Reference Group.

²Present address: Department of Fisheries and the Environment, Fisheries and Marine Service, Great Lakes Biolimnology Laboratory, 875 Queen St. E., Sault Ste. Marie, Ont. P6A 2B3.

Printed in Canada (J4430)
Imprimé au Canada (J4430)

and with preserving the pristine nature of the upper Great Lakes, the two governments signed, April 1972, the Canada-U.S. Agreement on Great Lakes Water Quality and assigned the IJC special responsibilities and functions in overseeing its implementation. The Agreement provides a mechanism for jointly attacking the known pollution problems in the Great Lakes and identifying new problems in water quality. The concern expressed by the Governments for protecting the upper lakes was reflected in the establishment of the Upper Lakes Reference Group (ULRG), a reference group to IJC as specified in the Agreement. This group was charged with undertaking a comprehensive study of pollution problems in Lake Superior, Lake Huron, and their connecting waters and reporting their findings to IJC. It is within the ULRG framework that the research reported within this volume was undertaken.

The oligotrophic upper Great Lakes have shown little environmental change since the turn of the century (Beeton 1969) although instances of localized altered water quality have occurred. In general, the effect of local perturbations in an aquatic ecosystem depends upon the nature and behavior of the particular chemical species, the physicochemical characteristics of the receiving water, and the response and/or susceptibility of the resident biota. Because of the notable localized nature of altered water quality in the upper lakes, the following studies were designed to determine wastewater effects, in time and space, through coordinated studies on physical dispersion and chemical and biological characteristics. Although such a framework could conveniently fit the study of almost any shoreline point-source discharge to a receiving water body, a pulp and paper mill was chosen because of the presence of many such mills in the upper Great Lakes system and its recognized and potential perturbative effect on aquatic ecosystems. The requirement for increased understanding of perturbative effect resulted in this joint undertaking by the Ontario Ministry of the Environment and the Department of the Environment.

In 1973, a feasibility study was undertaken at the American Can Co. kraft mill at Marathon, Ont. (Fig. 1). Generally, results of these experiments served primarily to redirect experimental approaches, especially methods to follow plume centerline paths, and led to the final selection of Nipigon Bay as a more appropriate study site. Research reported herein, therefore, results from studies jointly undertaken in Nipigon Bay, Lake Superior, during summer 1974. Results of that research are chronologically presented in this volume in the following categories of convenience:

- i) Effluent dispersion and plume processes
- ii) Ecosystem response and features not necessarily confined to discrete plumes
- iii) Testing of effluent effects upon biota
- iv) Plume oriented biological studies.

The Red Rock Mill

The Domtar Red Rock mill (Fig. 2) is a dual product mill with an approximate annual production of 61,000 t of newsprint and 203,000 t of kraft linerboard. The linerboard is used primarily in the manufacture of corrugated boxes. The mill began production as an unbleached sulphate (kraft) pulp mill in 1945. In 1948, a groundwood pulp mill was added to the operation. In 1954, a paper machine for the production of kraft linerboard was added and the original paper machine was converted to the production of newsprint from groundwood. A series of process changes for environmental improvement of the effluent has occurred during the mill's recent history. Prior to studies reported here, log digesters were phased out, a causticising plant and the kiln were installed to reduce losses of calcium carbonate, and the black liquor handling system

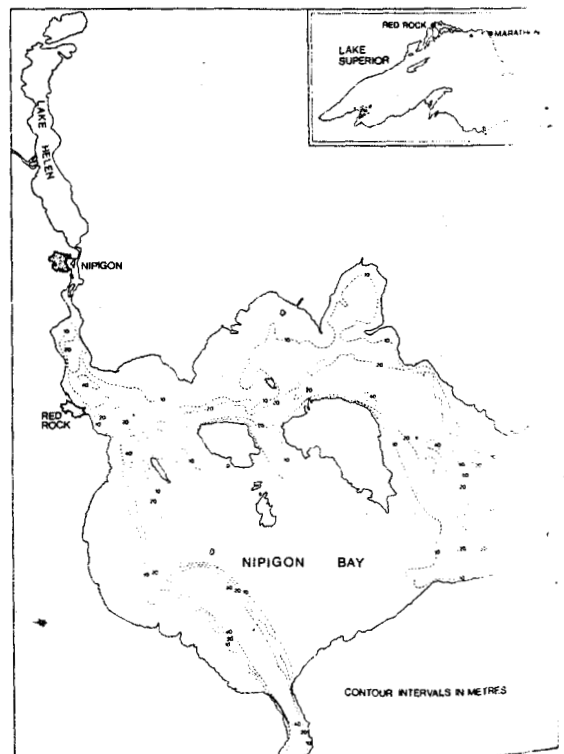


FIG. 1. Lake Superior showing location of Marathon and Red Rock including Nipigon Bay.



FIG. 2. Aerial photograph of the Domtar Red Rock mill, Nipigon Bay.

was tightened. Perhaps one of the most important modifications was the installation of an external treatment clarifier in 1973 for removal of fiber from wastewater. Following these studies, a condensate steam stripper was installed to eliminate volatile (primarily sulphurous) odorous and toxic materials.

Until 1973, most logs destined for the mill were transported by local waterways, primarily the Nipigon River (Fig. 1). Jack pine and black spruce were floated to storage areas in Lake Helen or Nipigon Bay. At the mill, logs were withdrawn from the water, cut to lengths and introduced to the pulping process. Today, wood arrives by truck or train either as logs or chips.

The two most important North American pulping procedures, chemical and mechanical, are both used at the Red Rock mill. Pulping of wood can be carried out by four methods: chemical, semi-chemical, chemi-chemical and mechanical with the order representing increasing yields of pulp (from about 42 to 95%) from available

cellulose fiber. Kraft pulping involves the use of sodium hydroxide and sodium sulphide which dissolves lignin from the wood in such a way that the cellulose fibers can be separated, i.e. pulped. Groundwood pulp is produced by mechanical separation of fibers by friction against stones (for further details of both processes see Tomlinson 1968). At the Red Rock mill, groundwood pulp is currently used only in the newsprint operation where it is combined with approximately 20% of semibleached pulp.

Residual amounts of lignin in the pulp can be removed by chlorination, thereby increasing paper brightness. The reaction products include carbon dioxide, water, and a variety of cleaved and uncleaved chlorinated and unchlorinated aromatics. Resin acids, fatty acids, and terpenes which are also present in the effluent appear to form the primary known toxic constituents.

Although the Red Rock wastewaters are discharged through one canal entering Nipigon Bay (Polak and Palmer 1977) three mill process

streams converge into this one discharge. An "uncontaminated" stream (approximately $10 \text{ m}^3/\text{min}$) of machinery coolant water joins a low suspended solids stream ($13.7\text{--}18.2 \text{ m}^3/\text{min}$) containing materials from paper machines, kiln causticizing area, bleach plant, etc. near the mill. The largest stream ($40.9\text{--}50.0 \text{ m}^3/\text{min}$) comes from the clarifiers which remove wood fiber from wastewaters of paper machines, wood room, ground-wood mill, and the kraft digester/washer screen area. Additionally, the town of Red Rock discharges sewage waste ($1.6 \text{ m}^3/\text{min}$) via the same discharge canal. Process waters are defoamed using commercial defoaming agents and wastewaters pass under a series of foam barriers from which they flow into Nipigon Bay.

Nipigon Bay

Nipigon Bay, in the northernmost corner of Lake Superior (Fig. 1), is fed primarily by the Nipigon River which enters the bay at the townsite of Nipigon, the major settlement of the watershed. The river has delivered, over the period 1950 to 1968, a mean annual flow of $365.3 \text{ m}^3/\text{s}$. This annual mean flow has varied by a factor of 2 ($245.2 \text{ m}^3/\text{s}$ in 1973 and $495.5 \text{ m}^3/\text{s}$ in 1969). Flows during the months of June, July, and August, the timing of this study, are generally far above the annual mean. In 1974, mean annual flow was $387.9 \text{ m}^3/\text{s}$ and monthly means were 563.5 , 566.3 , and $498.3 \text{ m}^3/\text{s}$ for June, July, and August, respectively.

The shores of Nipigon Bay are girdled by ranges of high, imposing rocky hills rising up to 200 m above the lake. Nipigon Bay itself extends about 16 km south and 40 km east from the entry of the Nipigon River. Two primary channels exist in the bay. The channel running south cuts between Five Mile Point, just south of the Domtar mill, and Burnt Island. The other channel parallels the northern shore of the bay. These channels tend to govern main directions of water flow (Polak and Palmer 1977).

These waters once supported a wide variety of fish species including lake trout, walleye, whitefish, and lake herring; however, the area has never attracted a major tourist industry (German 1966). These once abundant fish stocks are now limited or rare. A precipitous decline in walleye, the last of the most sought-after commercial stocks, was observed during 1958-67 (Ryder 1968). Commercial fishing catches have periodically been rejected for sale because of objectionable taste and odor. Many studies presented herein address, directly or indirectly, this aspect.

No definitive answer was forthcoming, however, either as to responsible compounds or mode of action.

Red Rock Studies

Contributions provided herein only partly achieved an inherent goal; namely, to model the fate and effect of a perturbative process affecting a nearshore upper Great Lakes environment. Conversely, studies neither lacked cohesion nor failed to achieve their original stated intent. Pervasive problems became apparent on site in 1974 and became clearer when chemists began tasks of compound identification, modellers attempted to describe the processes, and biologists sought factors governing observed responses. The lack of hydrologic understanding of Nipigon Bay was likely the largest obstacle, and Brownlee and Strachan (1977), Brownlee et al. (1977), Sandilands (1977), VanderWal (1977), and Rokosh et al. (1977) had to infer certain behavior in terms of water masses in developing an understanding of broad based chemical, sediment, benthic macroinvertebrate or bacterial community alterations. Plume oriented studies, however, fared considerably better as dye, drogues, and current meters provided adequate data for inspecting the tendencies in dominant localized alterations.

Plume analysis (Minns 1977; Polak and Palmer 1977) indicated that an area of approximately 1.5 km^2 was exposed to concentrations of effluent greater than 1%. Only a few percent of that loss occurring along the plume centerline trajectory was accounted for by processes other than dilution (Johnson 1977). Sandilands (1977) found generally elevated levels of organic matter near the outfall. It was this area which likely contributed to depressed macroinvertebrate communities (VanderWal 1977) and to the proposed resuspension of sedimented particulate material (Minns 1977). The area of effect imposed by the altered water quality appears plastic, however, in that the area influenced varies with the factor examined. Proceeding from most to least sensitive in biotic communities the following general sensitivity pattern develops: bacteria (Rokosh et al. 1977), benthic macroinvertebrates (VanderWal 1977), phytoplankton and periphyton (Moore and Love 1977), zooplankton (Cooley 1977), and fish (Kelso 1977; Whittle and Flood 1977). Although the areas affected coincide with the distribution of persistent organic contaminants (Brownlee and Strachan 1977) and areas influenced only by high effluent concentration, the

ties between contamination and effect were not always direct. Nevertheless the most sensitive indicator appears to be bacteria while the least sensitive appears to be fish.

In general, severe ecosystem disruption, evidenced by depauperation or severe alteration in function, was restricted to an area no greater than 0.5 km² near the outfall. Progressive recovery occurred beyond this area. Persistence of organic compounds, e.g. dehydroabiatic acid, although not directly implicated in taste and odor problems in fish, reflected the potential influence of contaminants, should their effect be either sublethal or impart undesirable taste and odor to desirable fish stocks. Combined with the fact that not all effluent components were toxic, it appears that certain groups of organic material, natural or residual, may act in concert with substances injected directly into the wastewater and thus augment conditions.

Apparent lack of response by benthic macroinvertebrates (VanderWal 1977) following several years of suspended solid removal indicates removal of problem-causing organic compounds as an immediate abatement procedure. The local alteration in community structure further indicates that, once taste and odor-creating substances are eliminated or reduced, rehabilitation of depleted desirable fish stocks is warranted.

Acknowledgments

We, the Department of the Environment and the Ministry of the Environment, wish to thank the Domtar Packaging Company Limited for their unstinting aid throughout this study. In particular, we thank Dr G. H. Tomlinson, Dr W. H. Cook, S. S. Hessian, A. S. Kadzielawa, and R. Dupuis of Domtar.

Paul McDermott, Water Quality Branch, Inland Waters Directorate, spent many hours performing on-site water quality measurements. Many analyses of samples were performed by Water Quality Branch personnel in Burlington.

A number of persons and agencies within the Department of the Environment made the field work possible: R. Collins, W. Hyatt, G. Dunlop, C. Charlton, Great Lakes Biolimnology Laboratory; G. Koteles, B. Timmins, and their co-workers in Technical Operations of Inland Waters Directorate; Marine Sciences Directorate who provided launches and the Port Dauphine and M. Head, Marine Sciences Directorate, who helped in many ways.

- BEETON, A. M. 1969. Changes in the environment and biota of the Great Lakes, p. 150-187. In *Eutrophication: causes, consequences, correctives*. Nat. Acad. Sci. Wash. D.C.
- BROWNLEE, B., AND W. M. J. STRACHAN. 1977. Distribution of some organic compounds in the receiving waters of a kraft pulp and paper mill. *J. Fish. Res. Board Can.* 34. (This issue)
- BROWNLEE, B., M. E. FOX, W. M. J. STRACHAN, AND S. R. JOSHI. 1977. Distribution of dehydroabiatic acid in sediments adjacent to a kraft pulp and paper mill. *J. Fish. Res. Board Can.* 34. (This issue)
- COOLEY, J. M. 1977. Filtering rate performance of *Daphnia retrocurva* in pulp mill effluent. *J. Fish. Res. Board Can.* 34. (This issue)
- GERMAN, M. L. 1966. Preliminary report of the biological survey of Nipigon Bay, Lake Superior. Ont. Wat. Res. Comm. Rep. 19 p.
- JOHNSON, M. G. 1977. Caloric changes along pulp and paper mill effluent plume. *J. Fish. Res. Board Can.* 34. (This issue)
- KELSO, J. R. M. 1977. Density, distribution, and movement of Nipigon Bay fishes in relation to a pulp and paper mill effluent. *J. Fish. Res. Board Can.* 34. (This issue)
- MINNS, C. K. 1977. Analysis of a pulp and paper mill effluent plume. *J. Fish. Res. Board Can.* 34. (This issue)
- MOORE, J. E., AND R. J. LOVE. 1977. Effect of a pulp and paper mill effluent on the productivity of periphyton and phytoplankton. *J. Fish. Res. Board Can.* 34. (This issue)
- POLAK, J., AND M. D. PALMER. 1977. Concentration pattern of chemical constituents in a paper mill's effluent plume: dynamics and model. *J. Fish. Res. Board Can.* 34. (This issue)
- ROKOSH, D. A., S. S. RAO, AND A. A. JURKOVIC. 1977. Extent of effluent influence on lake water determined by bacterial population distributions. *J. Fish. Res. Board Can.* 34. (This issue)
- RYDER, R. A. 1968. Dynamics and exploitation of mature walleyes, *Stizostedion vitreum vitreum*, in the Nipigon Bay region of Lake Superior. *J. Fish. Res. Board Can.* 25: 1347-1376.
- SANDILANDS, R. G. 1977. Effect of pulp mill effluent on the sediments of western Nipigon Bay, Lake Superior. *J. Fish. Res. Board Can.* 34. (This issue)
- TOMLINSON, G. H. 1968. Pulp. In *Encyclopedia of chemical technology*. Vol. 16, 2nd ed. J. Wiley and Sons, Inc., New York, N.Y.
- VANDER WAL, J. 1977. Relation between Nipigon Bay benthic macroinvertebrates and selected aspects of their habitat. *J. Fish. Res. Board Can.* 34. (This issue)
- WHITTLE, D. M., AND K. W. FLOOD. 1977. Assessment of the acute toxicity, growth impairment, and flesh tainting potential of a bleached kraft mill effluent on rainbow trout (*Salmo gairdneri*). *J. Fish. Res. Board Can.* 34. (This issue)