STUDY PROGRAM ON PENTACHLOROPHENOL

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Abstract

In 1989, Hydro-Québec began a study program on pentachlorophenol (PCP), with a view to ensuring safe management of the product at all stages of its utilization. The topics under study include storage of treated poles, behavior of PCP in the environment, soil decontamination, water treatment, characterization and disposal of treated waste wood, and assessment of substitutes. This paper summarizes the progress made in each of these study areas, and gives a brief overview of the results, both obtained and expected.

Résumé

Hydro-Québec a débuté en 1989 un programme d'études sur le pentachlorophénol (PCP) dans le but d'assurer une gestion sécuritaire du produit à toutes ses étapes d'utilisation. Les champs d'étude couvrent l'entreposage des poteaux traités, le comportement du PCP dans l'environnement, la décontamination des sols, le traitement des eaux, la caractérisation et l'élimination des déchets de bois traité ainsi que l'évaluation des substituts. Le présent document résume l'état d'avancement de chacune des études et donne un bref aperçu des résultats obtenus et à venir.

Introduction

By providing long-term resistance against fungi and wood-eating agents such as insects, the treatment of wood considerably lengthens the service life of wooden poles and thus leads to better forest management, conservation of forest resources, reduction in operating costs of companies such as utilities, and safer working conditions where wooden scaffolds are used.

The main wood preservation products used in Canada are creosote, pentachlorophenol (PCP), and copper-, chromium- or arsenic-based inorganic salts such as chromated copper arsenate (CCA) or ammoniacal copper arsenate (ACA). In a document (1) submitted to the Expert Advisory Committee on Dioxins in 1982, the Canadian Institute of Treated Wood estimated that some 300 000 wooden poles are treated annually, constituting more than 70% of all the wood treated in Canada. Of these, an estimated 75% are treated with PCP.

In the U.S. there are already an estimated 100 million poles, and each year there are 1 to 3 million more, treated with PCP (65%), CCA (6%) or creosote (28%).

It can be seen from these figures that a very large portion of treated wood is treated with PCP. In 1981, it was estimated that of the 1 600 metric tonnes of PCP used in Canada, 1 536 tonnes were used for wood preservation.

A study (2) conducted for Environment Canada in 1988 gives quite a complete picture of how treated wood is disposed of in Canada. Based on a total of 9 million poles in Canada with a useful life of 35 years, the study concludes that about 250 000 poles are disposed of every year. To this must be added the treated wood in forms other than poles: for example, each year about 400 000 PCP-treated railway ties are disposed of. In almost all cases, the wood is either buried or burned.

Even though federal and provincial legislation is not yet too restrictive in this respect, pressure from environmental groups and the media is already forcing us to look for solutions that will be more acceptable, both economically and environmentally.

The appearance of new products without risk to human health or the environment is not expected in the near future. And even if it were, there would still be more than 10 million wooden poles, mostly PCP-treated, to be disposed of in Canada.

Study on Storage of PCP-Treated Wood at Hydro-Québec

This study, conducted in 1989 and 1990, resulted in quite a detailed picture of the storage of treated wood at Hydro-Québec. Ninety-two permanent storage sites were inventoried, ranked by size (stores of treated wood ranged from a few pieces to over 4 000 poles) and classified by land use (43 in urban areas, 38 on city outskirts, and 11 in farming areas). Of these sites, 9 were retained for more detailed analysis. Their natural and human environments and the quality of the water, air and soil were assessed, and the results were measured against available environmental standards.

The analyses showed a high level of contamination of surface soil by mineral oil and grease, PCP, and polycyclic aromatic hydrocarbons (PAHs). Below 50 cm, however, the contamination often becomes negligible.

After a review of the literature, recommendations were formulated on the siting standards applicable to new sites as well as on the design of both new and existing sites.

Over the next two years, an environmental assessment will also be conducted on the remaining storage sites, and the siting and design standards will be integrated into the company regulations.

Characterization of Treated Wood Waste

In early 1990, Hydro-Québec conducted a characterization study on treated wood waste. Under the Québec government regulation on dangerous waste, the leachings from solid waste must be analyzed in order to determine its classification.

The study was conducted on 40 wooden poles, including 12 untreated poles which served as the control group. Two types of wood, jack pine and red pine, were used in almost equal proportions. The 28 treated poles came from two suppliers. Twelve had been treated for less than a year, while the others ranged in age from one to 20 years.

Concentrations of all 10 elements analyzed--fluorides, arsenic, cadmium, chromium, copper, mercury, nickel, lead, selenium and zinc--were below the statutory limits. The same was true of the mineral oil and grease: only one value exceeded the detection limit with a concentration of 6 mg/L. Yet levels of 100 000 mg/kg had been identified in these poles during total extraction analysis.

The 3 specimens analyzed for polychlorinated biphenyls (PCBs) and hexachlorobenzenes (HCBs) showed results below the detection limit, which is significantly lower than the current statutory limits. Monocyclic aromatic hydrocarbons (MAHs) and halogenated hydrocarbons (HHs) were also within the limits in the 3 specimens analyzed.

Of 29 specimens analyzed for total phenolic compounds, 2 exceeded the limit of 2 mg/L, with results of 2,3 and 5,1 mg/L. A recent American study (3) gave similar results, but the statutory limit for PCP in leachings is 100 mg/L.

As for PAHs, the limit of 0,005 mg/L was exceeded in all 5 of the specimens studied. Only one specimen was analyzed for polychlorodibenzo-p-dioxins (PCDDs) and polychlorodibenzo furans (PCDFs): it showed 2,1 _g/L of OCDD, compared with the allowed maximum of 1,5 _g/L. For these latter analyses, there were too few specimens to allow us to conclude that the statutory limits were exceeded.

Behavior of PCP in the Environment

The purpose of this study is to determine the importance of various factors in the migration of PCP. The results will be used to improve pole siting so as to protect sensitive elements of the environment and reduce environment-related complaints.

Before we can establish siting standards for the use and storage of treated poles, we must find out how the product behaves in water, air and soil, and we must determine the main physical, chemical and biological factors behind its migration and

transformation. When PCP is used to treat wood, it is used in a solution of 95% oil and 5% PCP. Being in a solution of course influences how the product behaves in the environment. Data not currently available in the literature will be obtained through studies in the laboratory and the field.
In a recent study conducted for Hydro-Québec, the different methods for analyzing chemicals used by the utility--PCBs, PCP and various pesticides--were inventoried. With regard to PCP, these methods are very rudimentary. New methods have therefore been developed at IREQ, Hydro-Québec's research institute. This aspect of the study is the subject of another paper presented at this conference.

A predicting model will be created on the basis of laboratory and field data. This model will be used to predict the behavior of PCP according to the milieu in which it is found. At the moment, we are integrating data from the literature with data obtained from laboratory simulations. This too will be discussed in another presentation at this conference.

The complex system by which oil and PCP migrate through the environment is divided into five specific blocks. Each block includes the development of a mathematical model. The first model will simulate the movement of an oil/PCP solution inside the pole and along its surface. The next two blocks are related to the migration of PCP in aqueous or oily phase into unsaturated areas of soil. A fourth model will simulate PCP runoff along the soil surface.

Migration of contaminants into the water table will be modeled using a transversal dispersion analysis of the PCP/water mixture. All the models will be adjusted and calibrated in accordance with laboratory tests, field measurements and bibliographical research.

For both PCP and the oil/PCP solution used in wood preservation, bibliographical research was conducted on the following aspects: behavior in soil and water; migration and decomposition; products of decomposition; current standards; and current predicting models.

Next, the missing data needed to develop a predicting model were obtained through laboratory tests. The behavior of the oil/PCP solution was studied under different conditions in a controlled laboratory environment. We were thus able to calibrate the key parameters identified, for which values could not be found in the literature.

In a semi-controlled environment, a mass balance will be determined for PCP solution on the treated pole as well as in soil and water. This simulation will be conducted under climatic and meteorological conditions that are as realistic as possible.

Many of the existing predicting models have not been tested or validated in the laboratory or in the field, but are strictly based on data from the literature. For this reason, the results will be verified in the laboratory and in the field.

Finally, the model will make it possible to determine a minimum protective perimeter around PCP-treated poles, depending on the topographical, geographic and environmental conditions. The method must be simple and easy to apply, and must take into account most of the conditions prevailing in Québec.

Feasibility Study on Biodegradation of PCP in Treated Wood Waste

A feasibility study on biodegradation of PCP in treated wood waste was undertaken this year with funding by the CEA.

The study is essentially based on bibliographical research and laboratory tests conducted by two research teams in order to select micro-organisms capable of degrading PCP in a wooden matrix, and to determine optimum conditions for such biodegradation. The research is designed to determine the performance of aerobic and anaerobic bacteria as well as fungi on various initial substrata such as PCP-treated wood chips or sawdust. To ensure reliable results, a quality-control program will be developed and a protocol for measuring biodegradation performance will be established.

An exhaustive updating of the related literature has been carried out and will soon be published by the CEA. Although several studies have been conducted on PCP biodegradation, few deal with degradation in an anaerobic environment, and fewer still with degradation in a wooden matrix.

After a review of the literature, we were able to confirm the interest of developing a method using fungi as well as aerobic and anaerobic bacteria. Fungi deserve particular attention, since enzymes isolated in them are able to induce oxydation (lignin) and hydrolysis (cellulose) of the main elements of wood. This could facilitate access to the PCP locked within the highly stable cell structure of wood.

As a matrix for degradation treatment, wood has the advantage of being an additional source of nutrients. If the enzymes responsible for destabilizing the cell structure are present in sufficient quantity, this will ensure the presence of glucose, a substratum preferred by most micro-organisms. Moreover, because the absorption of PCP into wood can be reversed, the use of wood as a matrix makes it possible to treat high concentrations of PCP while protecting the micro-organisms living there.

Concurrent with this bibliographical research, laboratory tests were conducted on pretreatment of wood. The first tests identified a number of technologies that could facilitate access by micro-organisms to PCP in wood.

The laboratory biodegradation tests got under way recently and will continue until 1992, using certain bacterial strains suggested in the literature as well as some original strains.

The results of this study could eventually be used to conduct pilot tests and could lead to the development of industrial waste wood treatment processes.

Treatment of PCP-Contaminated Soil

Hydro-Québec has several yards where it stores treated poles until they are needed for the power distribution system. Soil characterization studies on these yards have shown superficial contamination by PCP and mineral oil.
In 1989, a study was undertaken to determine the effectiveness of a biological process in decontaminating PCP-contaminated soil. The soil used in the study came from an old storage yard at Alma, Québec, and had maximum residual PCP levels of more than 100 mg/kg.

Laboratory tests conducted by Biogénie Inc. showed that selected bacterial strains were able to degrade the PCP, provided they had a chance to adapt to it gradually. A 77,5% reduction in PCP content was observed after the soil had been incubated for only 69 days.

Armed with these results, Biogénie Inc. conducted a pilot test on 100 cubic metres of soil in the Alma storage yard, during the summer of 1990. The mound of contaminated soil was placed on a paved surface so that the leaching water could be channeled off into an underground tank. To ensure aeration, perforated pipes connected to a booster pump were placed at the bottom of the mound. The mound was sprinkled periodically with water from the tank, which was checked to ensure optimum proportions of fertilizer, surfactant, co-substratum and micro-organisms. The soil was also covered with a membrane to minimize losses by volatilization. After 4 months of treatment, the PCP content went from 115 mg/kg to 1,9 mg/kg in the fine soil fraction (i.e. less than 2,38 mm diameter). These results indicate that the biological process is indeed effective and can reduce soil contamination to the level required under Criterion B of the soil rehabilitation policy of the Québec Ministry of the Environment, i.e. 1 mg/kg.

Treatment of PCP-Contaminated Water

Each year, Hydro-Québec receives complaints from individuals concerning the contamination of wells by PCP and mineral oil residues. In addition, runoff from treated-wood storage yards contains relatively large quantities of PCP and mineral oil, in some cases exceeding the levels allowed under municipal by-laws governing effluent in storm sewers.

Given that some of these situations could lead to high costs for the utility, Hydro-Québec undertook bibliographical research to find ways of treating contaminated water and rendering it suitable for its intended purpose. A total of 18 databanks were consulted.

This research showed that at present, the use of activated carbon is the most effective known method for our needs.

However, contact with decontamination researchers in the textile industry has led us to consider another possibility based on chitozene and its derivates. Hydro-Québec is about to reach an agreement with the research arm of the Textile Technology Centre in Saint-Hyacinthe, Québec, to evaluate the performance of this product and compare it with that of activated carbon under identical conditions. The results of this study could lead to a prototype filter using chitozene as a reactive attached to a textile. The first results are expected in the spring of 1992.

Toxicology and Ecotoxicology of Wood Preserving Agents

The purpose of this study is to summarize data on the toxicology and environmental transformation of the principal wood preserving agents, based on a complete survey of the relevant literature.

This data will make it possible to identify the potential risks to the environment and public health involved in using these products.

The principal agents considered in this study are PCP, creosote, copper naphthanate, chromated copper arsenate (CCA), ammoniacal copper arsenate (ACA), and ammoniacal copper quaternary (ACQ). In connection with PCP, the literature survey consisted in updating information on the basis of a 1987 document on PCP published by the World Health Organization (4).

Very little information is available on the toxicology and environmental transformation of copper naphthanate and arsenic salts such as CCA, ACA and ACQ. For this reason, the study focused mainly on the elements making up such compounds, e.g. arsenic, chromium, copper and ammonia.

Creosote seems to be more persistent in the environment than PCP. The transformation of arsenic salts is not as well documented; nevertheless, leaching and combustion of treated wood may be a possible source of arsenic and chrome in the environment. Available data on the toxic effects of PCP, creosote, CCA and ACA on animals have essentially been obtained through laboratory testing, using doses which are generally higher than the concentrations found in the environment. For copper naphthanate, on the other hand, no toxic effects on animals have been reported.

As for risk to human health, PCP is potentially teratogenic and mutagenic, while creosote is potentially mutagenic and carcinogenic. The elements making up arsenic salts, such as arsenic and chromium, are carcinogens and have a serious level of systemic toxicity. Of all the chemicals studied, copper naphthanate is the only one with a low level of toxicity in laboratory animals and in humans. However, the toxicokinetics and metabolism of copper naphthanate are not very well known.

This study must be followed up with an analysis of risk to public health and the environment caused by exposure to poles treated with these preservatives. A quantitative risk assessment will lead to a better evaluation of the intensity of potential impacts on the population. Such an analysis will provide all the scientific information needed to support management decisions.

References

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