Solid Waste Incineration in a Saskatchewan First Nation Community: A Community-Based Environmental Assessment of Dioxins and Furans

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Abstract

The Minister of Indian and Northern Affairs Canada (INAC) assumes the responsibility for the operation of waste dumps and landfills on First Nations Communities and although INAC has a fiduciary responsibility for waste disposal, most waste sites operated on First Nations communities remain unregulated. The incineration of solid waste is a form of waste disposal that has been conducted for years on Saskatchewan First Nations communities. The safety and acceptability of the solid waste management practice of incineration is a serious concern for many community members from both human and environmental health perspectives. Dioxins and furans are toxic and persistent chemical pollutants formed through the combustion of chemical and solid waste materials and are considered toxic under the Canadian Environmental Protection Act. Federal toxic management policies are currently aimed to virtually eliminate them from the Canadian environment. Due to the inherent nature and persistence of these chemicals in the environment, a preliminary investigation, part of a larger community-based participatory research study assessing historic and current waste practices, was initiated to determine environmental levels of dioxins and furans in environmental media in a Saskatchewan First Nation community. The Mistawasis First Nation in partnership with the Saskatoon Tribal Council, Saskatchewan Research Council (SRC), and the University of Saskatchewan (U. of S.) investigated the presence and concentrations of dioxins and furans in groundwater, soil, and ash samples collected from the community's active waste disposal site. The chemical analysis of soil and ash samples indicated the presence and concentrations of dioxins and furans well above the Canadian Council of Ministers of the Environment (CCME) soil quality guidelines for the protection of human and environmental health. Groundwater samples collected for analyses had no measurable concentrations of dioxins or furans. These findings suggest that waste incineration releases dioxins and furans to the soil and ash. Further environmental assessment is required to gain a better understanding of the extent of dioxin and furan release to the environment through the practice of waste incineration and of the potential health risks associated with exposures to dioxins and furans generated through waste incineration.

Introduction

Many First Nations communities across Saskatchewan are concerned with the unregulated solid waste management practices within their communities. Although the Minister of Indian and Northern Affairs Canada (INAC) assumes the responsibility for the operation of First Nation community waste dumps and landfills and has a fiduciary responsibility[1] for their waste disposal, most waste sites in operation remain unregulated. First Nations views have typically gone unheard and have had little influence, at points of authority, to maintain the balance required to endorse appropriate environmental protection laws and prompt enforcement actions on their lands.

1. In this context, fiduciary responsibility refers to the responsibility of an organization, such as Indian and Northern Affairs Canada, to handle finances of waste management for First Nations communities in Canada.

Compounded by inadequate funding to address environmental issues and the past industrial exploitation of First Nations land, the safety and acceptability of many solid waste management practices in Canada's First Nations communities has become a serious concern. Historically, poor management, monitoring, and remediation of solid waste facilities across Canada's First Nations communities and the lack of current resolve over this issue has left many First Nations people feeling the consequences of pollution to their rivers, land, and air.

There is a vast body of research on the potential environmental and human health effects of wastes and poor waste management practices (Rushten, 2003). The potential for human and environmental health effects associated with poor waste management practices has been a long-standing concern for many First Nations communities across Canada. Most western nations have environmental agencies, policies, statutes, regulations, and mechanisms for evaluating the possible impacts of waste management, for monitoring the continuing effects of existing waste management practices and for adjudicating charges of environmental damage (Hamer, 2003; Meske, 1993). Although several agencies and policies have been developed to protect people from environmental hazards in Canada, no equivalent mechanisms exist at present within the terms of self-government agreements to enable First Nations people to control environmental impacts on their lands. Historically, First Nations have been left at the margins in policy development and at present the avenues for their participation in federal, provincial, and territorial review processes are not clear or satisfactory (Indian and Northern Affairs Canada, 2004). Although the Minister of Indian and Northern Affairs Canada (INAC) has the responsibility under the *Indian Reserve Waste Disposal Regulations* (IRWDR), to grant permits (pursuant to section 5 of the regulations) for the operation of waste dumps and landfills, many sites within Saskatchewan remain unregulated.

Many First Nations communities have become increasingly concerned about the adverse effects that environmental contaminants have on human health and the health of the environment on which these communities are highly dependent (Crowe et al., 2001; Dillon, 1983). More specifically, the safety and acceptability of the solid waste management practice of incineration has become a serious concern for many community members from both human and environmental health perspectives. Presently, open-air dumps, coupled with trash burning, are common modes of waste disposal on First Nations communities within Saskatchewan. Both the Saskatoon Tribal Council Health and Family Services Inc. (STC) and the Health Canada

Regional Environmental Health officer for the Saskatchewan Region have identified the potential for contamination of air, soil, surface and groundwater supplies through the practice of waste incineration as a top priority. Monitoring of air, soil, surface and groundwater in the areas of waste incineration on many First Nations communities is not currently performed. Methods of dump and burn came to a halt in most parts of Canada with the enforcement of new clean air regulations in the late 1960s but they continue to be practiced in First Nations communities. The burning of wastes leads to the production of dioxins, furans, and other hazardous substances, which may be released into the atmosphere and deposited onto soil and ground/surface water bodies.

Dioxins and furans are toxic, persistent, and bioaccumulative chemical pollutants formed through uncontrolled burning and industrial processes (Menzer, 1991; Tiernan et al., 1985). Industrial sources of dioxins and furans to the environment include incinerators (Olie, 1980), the manufacture of chlorinated organics, and coal-burning power plants (Tiernan et al., 1985). Dioxins and furans are also released to the environment through nonindustrial sources that include residential wood burning, incineration of household trash, and diesel exhaust (Shibamoto et al., 2007). Dioxins and furans are also produced through the natural process of a forest fire. However, the largest source of dioxins and furans to the environment in Canada is the large-scale burning of municipal and medical waste (Health Canada, 2006; Environmental Protection Agency [EPA], 2004).

The term "dioxin" is commonly used to refer to a family of chemicals that share chemical structures and characteristics. These compounds include polychlorinated dibenzo dioxins (PCDDs) and polychlorinated dibenzo furans (PCDFs). There are 210 different dioxin and furan compounds and their demonstrated ability to cause adverse health effects or toxicity varies widely (Van den Berg et al., 1998; Schecter et al., 2006). Generally 17 of the total 210 dioxin and furan compounds characterized are the focus of regulatory action and environmental and human health concern (Health Canada, 2006; Menzer, 1991; Schecter et al., 2006). The most toxic of the dioxin and furan compounds is the molecule 2,3,7,8-tetrachlorodibenzo-p-dioxin or TCDD (Van den Berg et al., 1998).

The toxic effects of dioxin and furan compounds have been extensively studied in laboratory animals. The health effects in humans have been assessed in individuals exposed to these compounds through industrial accidents, contaminated food, and occupational settings (Schecter et al., 2005; National Toxicology Program [NTP], 2004). To date, studies indicate that di-

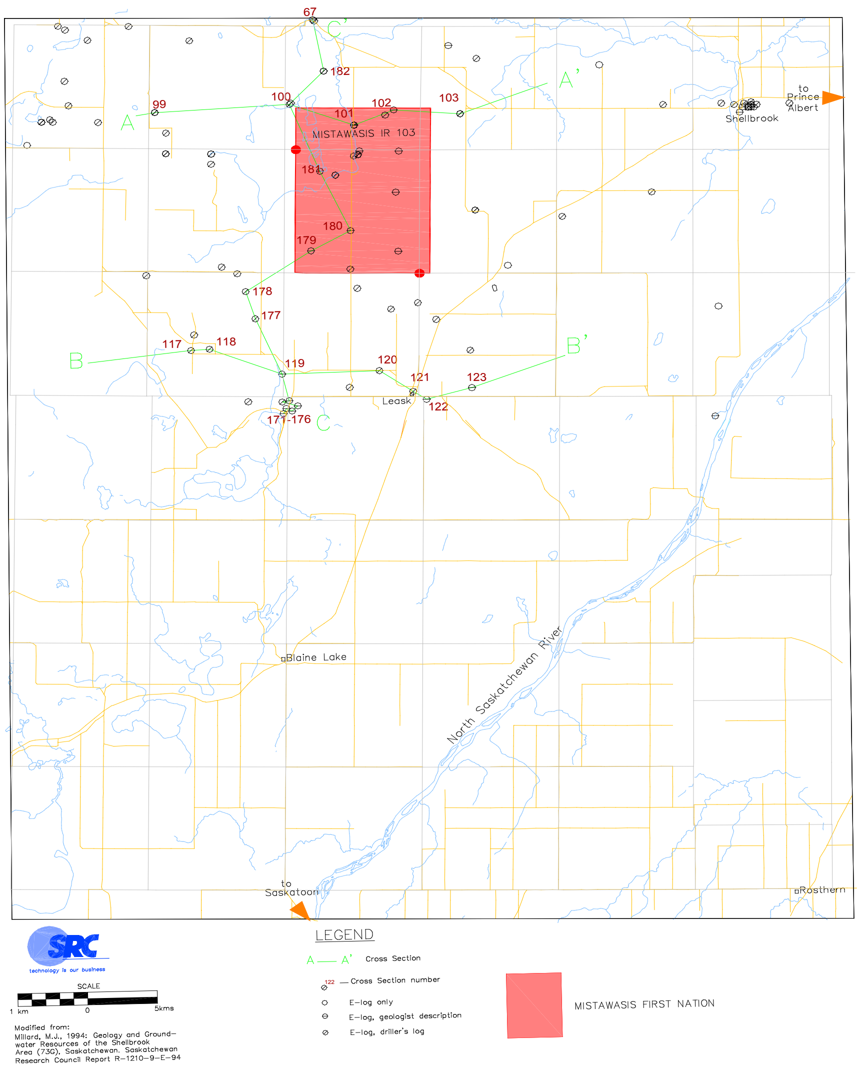

Figure 1. Location Map

oxins and furans have the potential to produce a range of adverse health effects in laboratory animals and humans. The health effects associated with human exposure to dioxins and furans include skin disorders such as chloracne, impairments to the immune, endocrine, reproductive, and developing nervous system and certain types of cancer (Health Canada, 1997; Environment Canada, 1990; CCME, 2005; Schecter et al., 2006; Arisawa et al., 2005; Birnbaum et al., 2003).

The past inappropriate management, monitoring, and remediation of solid waste facilities in the Mistawasis First Nation, located 68 km west of Prince Albert, Saskatchewan, has generated a range of economic, human, and environmental health concerns within this community. Elders expressed concerns about the "coughs and sore throats" of nearby residents as a major concern. The historical and current burning of waste both in backyard waste disposal pits and in larger dumps was a major concern in waste disposal practices. The environmental impact of historical and current practices of garbage incineration and the potential for dioxin and furan generation and release to the environment as a result of these incineration practices was of particular interest to this community. Members of the Mistawasis First Nation as well as the Health Directors of the community initially raised the concerns regarding waste incineration. These concerns were then brought forward to the Saskatoon Tribal Council and then to the Federation of Saskatchewan First Nations (FSIN). Following the communication of these concerns, a community-based participatory research project (CBPR), initiated by the Mistawasis First Nation and the Saskatoon Tribal Council Health and Family Services Inc., in partnership with the Saskatchewan Research Council (SRC), and the University of Saskatchewan (U. of S.), commenced in August 2004 to investigate concerns related to waste disposal in this community. As part of the overall community-based participatory research project, a preliminary investigation of the presence and concentrations of dioxins and furans in groundwater, soil, and ash samples collected from the community's active waste disposal site was performed. A detailed environmental and human health investigation of the effects of waste incineration within this community was unfortunately outside the scope of this study. However the main purpose of this investigation was to provide Mistawasis with critical preliminary information required for future regulatory initiatives, funding for remediation, monitoring, and management of their waste site on and/or off their reserve.

Methods and Materials

A community-based participatory action research design (Macaulay et al., 1998; 1999; Israel et al., 2003; Grenier, 1998) was employed to investigate the potential environmental impacts of waste incineration through the measurement of dioxin and furan concentrations in environmental media collected from the Mistawasis First Nations active waste disposal site. Community-based participatory research increases the voice of communities in identifying health and environmental issues. It enhances the relevance and validity of research by ensuring that communities share in the selection and design of research projects, gain skills, share in dissemination and utilization of research results (Macaulay et al., 1998). The key features of the participatory research methods included developing respectful and collaborative partnerships among researchers and community members; gaining permission and guidance from Chief and Council, community members, and Elders to conduct field visits and work; serving the research interests and needs of Mistawasis First Nation, and building community capacity in the field of environmental science through participation of community members in field site activities and environmental sampling.

Respectful and collaborative partnerships between researchers and community members were developed through a process of respectful communication initiated at the research preparation stage of the dioxin and furan investigation and prior to any data collection. Researchers from the University of Saskatchewan and the Saskatchewan Research Council, the Chief and Council, the Health and Environmental Directors, and the Environmental Health Officer (EHO) of the community met on several occasions to discuss roles, responsibilities, timelines, objectives, and goals of the research project; community protocol and engagement of community members; enhancement of community capacity; principles of ownership, control, access, and possession; and dissemination of research information. All meetings between partners were conducted with the understanding of "safe ethical space" (Ermine, Sinclair, and Jeffrey, 2004) where conditions are created for respectful dialogue between scientists and community. Each research partner was respected, was free to exchange ideas, and was provided the opportunity to understand the voice and intellect of the other (Ermine, Sinclair, and Jeffrey, 2004). All partners were considered experts with complementary knowledge and skills. Prior to the initiation of the dioxin and furan investigation, a contribution agreement, outlining the terms of the research activity, was drawn and subsequently signed by all partners involved in the research project.

Consistent with the principles of community-based participatory research, all members, including those from the community and research institutions, were involved in all aspects of the investigation (Israel et al., 2003). Chief and Council, the Environmental Health Officer, and the Health and Environmental Directors provided guidance to the scientists on community protocol and engagement, summarized community concerns, and suggested potential data collection sites. During initial discussions, it was agreed that

Elders of the community would be interviewed, in focus groups, on topics of waste disposal and health. Through interviews, Elders provided information on past and present waste disposal, sites and monitoring, and management practices in their community. Elders also spoke of health issues related to waste incineration at the active waste site due to its proximate location to community housing. Elders indicated water quality was a major concern for the people on the reserve and there was a need for waste to be cleaned up and moved off the community. Taking into account the information provided by Elders, initial conversations with the Health and Environmental Directors, Chief and Council, as well as the Environmental Health officer, it was clear that the current waste site was of immediate concern to the community and sampling for dioxins and furans was performed at this site.

Community involvement, knowledge transfer, and education were central goals of the community-based participatory research project. The Environmental Health Officer was responsible for the collection of soil and ash samples from the active waste site. A Mistawasis First Nation graduate was employed for the summer and conducted water sampling with guidance and instruction from the EHO. The graduate was also responsible for compilation of results and data analyses. High school students from the Mistawasis First Nation participated in a hands-on experience at the U. of S. and SRC laboratories. Coordinated in partnership with the community, two Elders, two chaperones, and seven students from Mistawasis First Nations engaged in a two-day science quest where students learned and applied research techniques utilized in toxicological and environmental assessments of chemical contaminants. Following their participation, students shared their experience with their peers at the community school.

The purpose of this investigation was to provide Mistawasis First Nation with critical preliminary information required for future regulatory initiatives, funding for remediation, monitoring, and management of their waste on and/or off their reserve. Results of the dioxin and furan sampling were brought back to Chief and Council for their input. Through discussions, various strategies for solid waste management were recommended. Recommendations included: consideration of off-site waste disposal, reduction and clean-up of unregulated backyard waste dumps, ceasing waste incineration, separation and control of hazardous waste disposal, continuous monitoring and/or remediation of the active waste site, and securing long-term stable funding. A final report outlining the issues of waste incineration, the results of the investigation and recommendations for waste disposal was provided to Chief and Council to facilitate a future proposal to INAC. A poster was created for the community Health Centre and the EHO presented the findings at the National Environmental Health Officers conference in Halifax, Nova Scotia.

To better understand the potential impacts of waste disposal practices on human and environmental health in First Nations communities, the project involved a comprehensive hydrological assessment and chemical analyses of groundwater, waste disposal site leachate, soil, ash, and subsurface gas. This article focuses on the dioxin and furan assessment conducted at the active waste site in operation at the Mistawasis community. The methodologies utilized for assessing the presence of dioxins and furans in soil and water samples collected from the community's active waste site are described below under field work and environmental monitoring. Briefly, four monitoring wells were installed at the active landfill to assess the impacts of waste incineration to groundwater. Groundwater, soil, and ash were sampled for dioxins and furans at each of these monitoring well locations.

Description of Active Waste Disposal Site

The active waste site was characterized as an open-air waste disposal dump. Discussions with community members and visits to the waste disposal site revealed that a formal geological site selection process was not conducted prior to the location assignment of the active waste disposal site in the community. The waste site was located in an area of silty sandy soils close to surface water features, was built without engineered liners, and leachate collection systems. Thus, the community's active waste disposal site was referred to as a "dump" as opposed to a landfill.

Field Work and Environmental Monitoring

Monitoring Well Installation

Groundwater monitoring wells were installed in and around the waste disposal dump to permit water level measurement and sampling of groundwater and leachate. The wells were constructed of 50 mm diameter threaded polyvinyl chloride (PVC) plastic pipe with manufactured well screens (Gartner Lee Limited [GLL], 1993). All constructed wells were tested to determine hydraulic conductivity of the formation, and to determine if wells were sufficiently responsive to the hydraulic flow system to provide reliable monitoring data. Monitoring wells were installed using a solid stem 3.25 inch auger, model Mobile B-10 drill rig. Monitoring wells were positioned so that there was one up-gradient ("background") monitoring location and two monitoring wells down gradient from the potentially impacted areas. The well up gradient from the waste disposal dump was installed to establish background water quality, and to establish water level elevations and hydraulic gradients for determining groundwater flow into, or below, the waste disposal dump. A line of three wells were situated down gradient from the dump and perpendicular to groundwater flow in the horizontal plane to detect and determine the extent and concentrations of any potential leachate plumes; to assess groundwater levels, flow directions, and flow rates; and to assess leachate impacts to receiving groundwater. All monitoring wells were surveyed using a level to provide an accurate elevation relative to a local datum and the positioning of these wells was established using a global positioning system (GPS).

Groundwater Sampling

Groundwater sampling was conducted as part of the waste disposal dump investigation to assess the presence and concentrations of dioxin and furan in the area of the active dump. Groundwater samples were collected from three groundwater monitoring wells and analyzed for the presence of dioxins and furans. Standard sampling protocols were utilized to ensure consistency and accuracy in the collection of water samples for chemical analyses from monitoring wells. The sampling protocols and guidelines derived by the Ministry of the Environment, Guidelines for Environmental Monitoring at Municipal Solid Waste Landfill Sites and the American Society of Testing Materials (ASTM) Standard D5 092-04e1; Standard Practices for Design and Installation of Groundwater Monitoring Wells were adopted to ensure that quality assurance and quality control (QA/QC) and consistency were achieved in the field. Groundwater sampling consisted of groundwater sampling equipment decontamination, well-water purging, sample collection, sampling equipment decontamination, and documentation of sample collection.

Solid Chemical Sampling

Solid chemical analyses were performed on soil and ash samples collected from the active waste disposal site in operation at Mistawasis First Nation. Ash and soil samples were retrieved from areas around the active waste site and analyzed for the presence of dioxins and furans. Three soil samples were collected from the immediate vicinity of the active waste disposal area. One control or background soil sample was collected from an area immediately east of the dump site. Two soil samples were collected from the south wall of the active Mistawasis waste disposal site. These soil samples were collected at a depth approximately 0.2-0.5 m below grade.

Three ash samples were collected from various locations inside the waste disposal pit. Two ash samples were collected within the waste disposal site. One of the ash samples collected was characterized as black charred ash with metal iron oxide present. The second sample was characterized as a white/black ash mixture of paper ash. The third ash sample, collected from outside the dump site, was a white/black ash mixture and contained some plastics and copper. These ash samples were composited into one sample and mixed to homogenize the ash sample (Mistawasis Ash Composite). In order to reduce the number (and costs) of samples for analysis, ash and/or soil samples are often composited.

High Resolution Gas Chromatography Mass Spectrometry (HRGC/HRMS)

Quality control/quality assurance was integrated into all phases of the sampling and analysis process. Analytical reproducibility was determined through replicated analysis of environmental samples. High resolution gas chromatography and mass spectrometry (HRGC/HRMS) is the standard method for dioxin and furan analysis in environmental matrices and was utilized to measure dioxin and furan in groundwater, soil, and ash samples collected for analyses. Dioxin and furans were measured by HRGC/HRMS analysis using Environment Canada method EPS 1/RM/19 (Environment Canada, 1990). Toxic Equivalents (TEQ) (expressed as 2,3,7,8-TCDD ppt equivalents) were calculated using individual congener Toxic Equivalency Factor(s) (TEFs) put forth by the World Health Organization (WHO) (Van den Berg et al., 1998). Toxic Equivalents or TEQs are used to report the toxicity-weighted masses of mixtures of dioxins/furans. TEQ denotes "toxic equivalent," a quantitative measure of the combined toxicity of a mixture of dioxin-like chemicals. Concentrations of the congeners polychlorinated dibenzodioxin/polychlorinated dibenzofuran (PCDD/PCDF) were used to estimate total dioxin/furans TEQ. These include: tetra-, penta-, hexa-, hepta- and octa-chlorinated dibenzodoxins and dibenzofurans. All samples were analyzed at Pacific Rim Laboratories Incorporated, Surrey, British Columbia, an accredited laboratory for dioxin and furan analyses.

Results

Groundwater

Groundwater samples were collected from three groundwater monitoring wells (Mist101, Mist102, and Mist104) and analyzed for the presence of dioxins and furans. The results of duplicate analyses of groundwater samples are summarized in Table 1. Results are presented in Toxicity Equivalents or TEQs for dioxins, furans, and total dioxins/furans.

The monitoring well water total dioxin and furan concentrations were calculated as 5.69 pg (picograms) TEQ/L (liter). The total TEQ/L was equal to the detection limit, indicating that there were no dioxins and furans detected in the groundwater samples collected from the installed waste disposal monitoring wells.

Table 1. Summary of Dioxin, Furan, and Total Dioxin/Furan Toxic Equivalents: Groundwater Samples

Sample Location	*Dioxin: WHO-TEQs (pg TEQ/L)*	*Furan: WHO-TEQs (pg TEQ/L)*	*Total Dioxins/Furans Toxic Equivalents (pg TEQ/L)*
Mist 101	3.63	2.06	5.69
Mist 102	3.63	2.06	5.69
Mist 104	3.63	2.06	5.69
Blank	3.63	2.06	5.69

Solid Chemistry

Soil and Ash Chemistry

Soil samples and a composite ash sample were collected from areas of the active Mistawasis waste disposal site and analyzed for the presence of dioxins and furans. Results are reported in Toxicity Equivalency Quantities (TEQ) in nanograms (ng)/kilogram (kg) of soil (dry weight, DW) and are provided in the table below. Table 2 provides the TEQs of individual congeners utilized to estimate the total PCDD/PCDF TEQ for soil and ash samples collected for analysis.

The concentration of dioxins and furans in the soil samples, collected from the south wall of the waste disposal site, ranged from 354 to 49.45 ngTEQ/kg soil DW and 103.18 to 726 ngTEQ/kg soil DW respectively. Background soil contained concentrations of dioxins (2.13 ngTEQ/kg soil DW) and furans (1.16 ngTEQ/kg soil DW) considerably lower than those measured in soils collected within the waste site. Total dioxin and furan concentrations measured in the two soil samples collected from the south wall of the waste disposal site ranged in concentration from 152.63 to 1,080 ngTEQ/kg soil DW. Total concentrations of these compounds measured in soil samples collected from within the waste site were considerably higher than the background or baseline concentrations of these chemicals in the soil east of the active

Table 2. Concentrations of Dioxin, Furan, and Total Dioxin/Furan Toxic Equivalents: Soils and Composite Ash.

Sample	*Mist Background Soil*	*Mist Soil # 1*	*Mist Soil # 2*	*Mist Composite Ash*
Dioxins				
Congeners	*WHO-TEQs (ng-TEQ/kg)*	*WHO-TEQs (ngTEQ/kg)*	*WHO-TEQs (ngTEQ/kg)*	*WHO-TEQs (ng-TEQ/kg)*
2,3,7,8-TCDD	0.50	13.00	1.80	310.00
1,2,3,7,8-PeCDD	1.00	240.00	34.00	630.00
1,2,3,4,7,8-HxCDD	0.10	18.00	2.50	190.00
1,2,3,6,7,8-HxCDD	0.16	30.00	4.00	380.00
1,2,3,7,8,9-HxCDD	0.13	24.00	3.60	330.00
1,2,3,4,6,7,8-HpCDD	0.23	29.00	3.50	430.00
OCDD	0.013	0.35	0.054	7.40
Total dioxin TEQ	2.13	354	49.45	2277
Furans				
Congeners	*WHO-TEQs (ng-TEQ/kg)*	*WHO-TEQs (ngTEQ/kg)*	*WHO-TEQs (ngTEQ/kg)*	*WHO-TEQs (ng-TEQ/kg)*
2,3,7,8-TCDF	0.05	9.20	0.87	270.00
1,2,3,7,8-PeCDF	0.05	11.50	1.60	55.00
2,3,4,7,8-PeCDF	0.5	355.00	49.00	8000.00
1,2,3,4,7,8-HxCDF	0.11	92.00	12.00	2200.00
1,2,3,6,7,8-HxCDF	0.10	73.00	11.00	1400.00
1,2,3,7,8,9-HxCDF	0.10	36.00	5.30	93.00
2,3,4,6,7,8-HxCDF	0.14	120.00	18.00	2400.00
1,2,3,4,6,7,8-HpCDF	0.095	24.00	4.70	640.00
1,2,3,4,7,8,9-HpCDF	0.015	5.60	0.68	60.00
OCDF	0.0013	0.18	0.026	3.70
Total furan TEQ	1.16	726.00	103.18	15122.00
TOTAL PCDD/PCDF TEQ	3.29	1081.00	152.63	17399.00

waste site of Mistawasis First Nation. According to the Canadian Soil Quality Guidelines (CSoQG) Chapter 7, the residential and park soil limit for total dioxins and furans is 4 ng TEQ/kg soil DW (CCME, 2006). The total dioxin and furan concentrations in soils collected from the south wall of the waste disposal site were 38 to 270 times above the CSoQG guidelines. The background soil sample was found to have concentrations of dioxins and furans slightly below the CSoQG objectives.

In the absence of widely accepted criteria for ash concentrations, ash results were compared to criteria established by the CSoQG Chapter 7 for residential and park soils (CCME, 2006). The concentration of dioxins and furans in composite ash ranged from 2,277 ngTEQ/kg soil DW to 15,122 ngTEQ/kg soil DW. The total dioxin and furan concentration reported in composite ash was 17,399 ng TEQ/kg soil DW, a concentration approximately 4000 times the CSoQG guideline. Total dioxin and furan concentrations in composite ash found in the present investigation were also demonstrated to be much higher than total dioxin and furan concentrations measured in the surface ash (159 ngTEQ/kg) and subsurface ash (107 ngTEQ/kg) collected at a waste site through previous investigation at another Saskatchewan First Nation community (Quest Environmental, 2004).

In general, soil samples collected from the waste site contained highly chlorinated dioxins and furans: 1,2,3,7,8-PeCDD was found to contribute 68% and 69% to the total dioxin TEQ of Mist Soil #1 and #2 respectively; 2,3,4,7,8-PeCDF was found to contribute 49% and 47% to the total furan TEQ of Mist Soil #1 and #2 respectively. Ash samples, like those of the soil samples, also contained highly chlorinated dioxins and furans, but at considerably higher levels: 1,2,3,7,8-PeCDD was found to contribute approximately 28% to the total dioxin TEQ; 2,3,4,7,8-PeCDF was found to contribute 53% to the total furan TEQ. Overall, penta- and hexa-chlorinated dibenzodioxins and dibenzofurans were significant contributors to the total PCDD/PCDF TEQ of soil and ash samples collected for analysis.

Discussion

In the present study, the presence and concentrations of dioxins and furans in groundwater, soil, and ash samples collected from the active waste disposal site of the Mistawasis First Nation was determined. The total dioxin/furan concentration of 3.29 ng TEQ/kg was determined for a background soil sample collected just east of the Mistawasis active waste site. This background level could be representative of the background soil dioxin and furan concentrations typically found in Mistawasis First Nation soils although more soil analysis is required to more accurately determine the background levels of these compounds. The soil background level of 4 ngTEQ/kg is considered representative of the mean background concentrations of dioxin/furans in Canadian soils by the CCME (2005). The American EPA (2003) has determined rural background concentrations in North American soil for dioxins and furans of 9.3 ngTEQ/kg. The background soil concentration of 3.29 ngTEQ/kg at Mistawasis First Nation is slightly below the mean background concentrations of dioxins and furans typically found in Canadian and/or North American soils. However, further analyses and collection of soil samples are required to provide a clearer, more accurate picture of the background soil concentrations of dioxins and furans in the soils of the Mistawasis First Nation.

Total dioxin and furan concentrations measured in soil and ash samples collected for analysis contained dioxin and furan concentrations above the CCME soil quality guidelines of 4 ngTEQ/kg for the protection of human and environmental health. Total dioxin and furan concentrations measured in soil samples collected from the south wall of the waste site ranged in concentration from 152.63 to 1,080 ngTEQ/kg. A few studies have been conducted to determine soil concentrations of dioxins and furans in the area of active municipal solid waste incinerators. Yashuhara et al. (1987) and Morita et al. (1987) measured dioxin/furan levels in soil near (exact location of soil sampling was not indicated) four municipal solid waste incinerators (MSWI) in Japan. The mean concentration of total dioxin/furan measured in these soils was 530 ng TEQ/kg. McLaughlin and Pearson (1985) measured soil concentrations of dioxins and furans at 11 sites approximately 0.1-0.2 km away from a municipal solid waste incinerator in operation in the city of Hamilton, Ontario. The geometric mean concentration for these 11 test sites was 380 ngTEQ/kg. Berlincioni and di Domenico (1987) assayed soil samples collected from five sites within a 1 km radius of a municipal solid waste incinerator in operation in Florence, Italy. The geometric mean of dioxin/furan soil concentration was 250 ngTEQ/kg. In general, previous studies have shown that total dioxin and furan concentrations in soils collected and analyzed near MSWI range in concentration from 250 to 500 ng TEQ/kg. The concentrations of total dioxins and furans in soil samples collected from the active waste site in this study varied slightly (2 times above) from those typically found in the soils near MSWIs suggesting that the practice of waste incineration is a contributing source of dioxins and furans to the soil environment in this community.

Ash or fly ash is defined as nonburnable residual particles left after trash is burned. Ash can also be carried by smoke and air. The total dioxin and furan concentration of 17,399 ng TEQ/kg was measured in composite ash samples collected for analyses from the Mistawasis active waste site. A study by the Agency for Toxic Substances and Disease Registry (ATSDR) that assessed the potential impacts of a landfill in Port Angeles, Washington found total dioxin and furan concentrations of 1800 ngTEQ/kg in ash samples that were collected for analysis. The concentrations measured in composite ash samples, collected in this investigation, were considerably higher than those found by the ATSDR investigation. Previous studies have shown that concentrations of dioxins and furans found in pine needles collected from trees surrounding MSWIs are very similar to those found in ash, air, and soil (Ok et al., 2002) suggesting that plants near MSWIs are affected by either MSWI soil, ash, and airborne ash. The present and previous findings of Ok et al. (2002) suggest that plant materials in the community of Mistawasis could be adversely impacted by dioxins and furans due to the present practice of waste incineration within their community. Future investigations to further assess the extent of dioxin and furan short and long-term release, to the environment, through waste incineration, could be achieved through analysis of vegetation, snowpack, soil, and air (Blais et al., 2003; Brzuzy and Hites, 1995).

Dioxins and furans are known to accumulate in animals and have been found in most species of wildlife surveyed. Detectable concentrations of dioxins and furans have been found in surface waters, tissues of fish, and farm animals (Startin and Rose, 2003). Thus there is strong potential for dioxins and furans to be transported from incinerator or waste site emissions to environmental media such as air, soil, and water, and then into human exposure media such as drinking water, food, and vegetation (Domingo et al., 2000). Detectable concentrations of dioxins and furans have been found in human body fat, blood, and milk (Schecter, 2006). Dioxins and furans have the ability to produce a wide range of toxicological responses in animals and, in sufficient doses, in humans. Recent information indicate that perinatal exposure to background soil concentrations of dioxins and furans (4ng TEQ/kg) are associated with a variety of subtle clinical immunological and neurodevelopmental alterations in human newborns (Schecter et al., 2005). The dioxin, TCDD, is considered a potent reproductive and immunological contaminant.

This investigation has provided some preliminary evidence on the levels of dioxins and furans in soil and ash samples collected from the active waste site of the Mistawasis community. The continuing evidence of toxicity at very low levels of exposure warrants further investigation and attention to current waste incineration practices on First Nations communities. Therefore, to gain a better understanding of the health risks and potential for human exposure to dioxin and furans, through waste incineration, it would be useful, in future assessments, to measure PCDD/PCDF concentrations and compare congener patterns of various environmental media found in and around waste incineration sites. Future samples collected for analysis may include; fly ash, bottom ash, ambient air, soil, pine needles, in addition to human blood.

Where and how to begin waste management programs is a critical issue for First Nations communities with limited resources. Finances are a key constraint for most First Nations communities. As a result, significant and stable funding for waste management and the monitoring of existing landfills needs to be established. Provincial and federal agencies must be made aware that First Nations communities such as Mistawasis are not only taxed financially but also in terms of available labour, technical expertise, and operational capabilities. Comprehensive solid waste management incorporates a diverse range of activities including reduction, recycling, segregation (separation), modification, treatment, and disposal — all of which have varying levels of sophistication. Various strategies for solid waste management could be considered in First Nations communities in partnership with federal and, if possible, provincial departments. Waste sites should be engineered and operated at modern standards and further environmental assessment should be conducted to more accurately assess impacts to human and environmental health.

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