TORONTO STAFF REPORT

November 4, 2004

To: Board of Health

From: Dr. David McKeown, Medical Officer of Health

Subject: Health and Ecological Risk Associated with Toronto Biosolids Pellets

Purpose:

To report on the human health and ecological risks associated with land application of Toronto biosolids pellets.

Financial Implications and Impact Statement:

There are no financial implications resulting from the adoption of this report. Any financial impacts for City departments stemming from implementation of the recommendations will be considered through future budget processes.

Recommendations:

It is recommended that the Board of Health request:

(1) that if the City proceeds with reconstructing the pelletizer plant and developing markets for biosolids pellet uses within the City and beyond, the Commissioner of Works and Emergency Services ensure the viability and safety of pellet utilization through adequate monitoring of the pelletizing process and testing of pellet quality, and through the adoption of precautionary measures regarding the use and storage of pellets, as detailed in Appendix A of this report;

(2) the Commissioner of Works and Emergency Services report to the Works Committee on amendments to the Toronto Sewer Use By-law to restrict the disposal of waste pharmaceuticals and untreated blood and blood products, including those from funeral homes and animal slaughter houses (abattoirs), into the sewage system;

(3) the Federal Minister of Health, Federal Minister of Agriculture and Agri-Food, and the Ontario Minister of Agriculture and Food ensure implementation of actions to prevent possible contamination of the sewer system from prions by:

(a) preventing animals showing symptoms of mad cow disease or similar illnesses transmitted through prions from being slaughtered in abattoirs, and to dispose of such animals in an appropriate manner; and

(b) requiring the placement of fine screens in abattoir drains so that prion-containing particles, if present, will not be able to pass into the sewer system;

(4) the Federal Minister of Agriculture and Agri-Food to:

(a) undertake studies, including laboratory-based research to address the potential bioavailability, phytotoxicity and/or ecotoxicity from chromium and copper with long-term use of biosolids pellets on urban parks and residential properties, so as to facilitate the development of appropriate new standards for chromium and copper in fertilizers; and

(b) establish standards for maximum permissible levels of chromium and copper in all fertilizers, for inclusion in the federal Fertilizers Act;

(5) the Ontario Minister of Health and Long Term Care to conduct, in consultation with the Ontario Minister of the Environment, a health study regarding the potential risks to human health from the use of biosolids cakes;

(6) the Medical Officer of Health report to the Board of Health on the findings of the Health Status Study for the South Riverdale and Beaches Community, as well as the Ashbridges Bay Treatment Plant Air Modelling Study, upon their completion;

(7) that this report be forwarded to the Works Committee for information and appropriate action; and

(8) the appropriate City Officials be authorized and directed to take the necessary action to give effect thereto.

Background:

In the early 1990s, the Works Department of former Metropolitan Toronto initiated an environmental assessment (EA) regarding planned modifications and improvement to the operation of the Ashbridges Bay Treatment Plant (ABTP). The environmental assessment is a requirement under the Ontario Environmental Protection Act. Many studies were conducted and options considered. A pilot project was initiated to apply 50% of dewatered sewage sludge (biosolids cake) on agricultural land in Ontario. By 1998, City Council made a decision to pursue

100% beneficial biosolids use (land application) and to construct a pelletization plant at ABTP to convert 50% of the dewatered cake into dry pellets.

At the March 1999 Council meeting, Council granted authority to WES to negotiate with USF Canada to design and build a biosolids pelletization facility, as well as to market and distribute the biosolids pellets. During the course of negotiating a marketing agreement, the Board of Health received a letter from Councillor Mihevc (dated November 29, 1999) requesting the Works Committee and the Board of Heath to direct staff to report on an on-going monitoring system with respect to the City's biosolids agreement to ensure against potential negative and environmental health consequences. This report was to be directed to both the Board of Health and Works Committee. At its meeting on February 21, 2000, the Board of Health requested the Medical Officer of Health to submit such a report to the Board, and to include comment on the health aspects of direct land application of biosolids.

During this time, WES participated in a mediation process (first initiated in 1998) with members of the local community as part of the original ABTP Environmental Assessment. As a result of the negotiation, the City agreed in June 2001 to fund the community's request for three studies related to the ABTP. The Medical Officer of Health was requested to commission and oversee these studies. The three studies commissioned by the Medical Officer of Health are: (1) Biosolids Pellet Review Study: Human Health and Ecological Risk Assessment; (2) Health Status Study for the South Riverdale and Beaches Communities; and (3) ABTP Air Modelling Study. The first study is completed and is the subject of this report. The remaining two studies are nearing completion and their findings will be reported to the Board in 2005.

Toronto Public Health initiated the Toronto biosolids review study after consulting with WES staff and the Implementation Compliance and Monitoring Committee (ICMC). The ICMC is a committee comprised of citizen volunteers, non-governmental organization representatives and signatories to the ABTP Environmental Assessment Mediation Agreement. The ICMC was established to advise the City regarding implementation of commitments made in the Mediation Agreement and to report annually on compliance with the Agreement. The scope of the biosolids review study was also informed by consultation with health units across Ontario, as well as with the Ontario Ministry of the Environment (MOE) regional and district offices with respect to concerns that the public has raised over land application of biosolids. The review examines the potential risks to people, plants and soil organisms, pets (cats and dogs), birds and other wildlife associated with three options for using pellets by the City.

This report to the Board of Health was prepared in consultation with staff from the Works and Emergency Services Department.

Comments:

Biosolids are products of the sewage treatment process, which consists of a combination of physical, chemical and biological processes. The solids remaining after anaerobic digestion of sewage sludge are dewatered to produce biosolids cake (30% solid, 70% water). The Ontario

Ministry of the Environment regulates the land application of biosolids cake in Ontario, including biosolids cake derived from Toronto's sewage treatment plants.

Biosolids pellets are products of the sewage treatment process and further heat-based processing in a pelletizer plant to create small solid granules with low moisture content. They have potential value as a fertilizer, and as a soil amendment that can improve the structure of soils. Biosolids pellets have greatly reduced pathogen content compared with biosolids cake. A comprehensive study was undertaken through Toronto Public Health to assess the health and ecological risk associated with long-term pellet use for 25 years on City-owned property (such as landfill cover seeded to establish a vegetative cover), on park land (such as City-owned parks and golf courses), and on residential property (such as lawns and urban food gardens). An explanation of the key findings of the study is provided in Appendix B. The Toronto Public Health study recommends that the Ministry of Health and Long-Term Care conduct a complementary study regarding the use of biosolids cakes.

The health component of the Toronto Public Health study examined the chemical and microbiological risk to young children (7 months to 5 years), adult residents and workers applying pellets on land. A quantitative risk assessment was completed for the 11 metals regulated in biosolids, as well as for PCBs, dioxins and furans. The assessment of microbiological risk was based on an evaluation of the extent to which the pelletizer technology provided the conditions necessary to destroy microorganisms that might be present in sewage sludge. Overall, the study found that there was negligible risk to human health from possible chemical pathways of exposure arising from pellet use in all scenarios assessed.

Regarding microbiological risk, there is less certainty than with the assessment of chemical risk; however, overall, microbiological risk is likely very low. Pelletization appears to provide the conditions for effective destruction of micro-organisms. However, to ensure safety, several recommendations are directed at providing confirmatory monitoring for process temperature, process duration, humidity levels and indicator biological agents to verify that microbiological risks are negligible. The study also suggests that the use of pellets on grass with extensive bare patches should be avoided until such time that microbiological monitoring results can demonstrate negligible risk from accidental ingestion of pellets visible and readily accessible to young children. Use of pellets on turf free of bare patches is not likely to be of concern.

The study notes the importance of the City's stringent Sewer Use By-law in reducing the levels of most metals in sewage sludge, and the need to continually strengthen the Sewer Use By-law. Additional measures are proposed to enhance the by-law such as preventing the disposal of waste pharmaceuticals and untreated blood and blood products, including those from funeral homes and animal slaughter houses (abattoirs). An important way to ensure the long-term viability of a biosolids program is to prevent substances not easily destroyed at the treatment plant from entering the sewage system in the first place. The adoption of precautionary measures can address new and emerging concerns regarding chemical and biological agents. The federal Minister of Health, federal Minister of Agriculture and Agri-Food, and the Ontario Minister of Agriculture and Food all have important roles in preventing the entry into the sewer system of potential hazards such as prions arising from animals showing symptoms of mad cow disease or similar illnesses. The potential risk for exposure to prions through Toronto's biosolids pellets is very low, in large part because there is no known source of prions in the area, nonetheless, precautionary measures are warranted.

The ecological component of the biosolids pellets study suggests that overall risks to pets and wildlife from long-term (25 year) pellet use are negligible. There is some concern regarding the impact of chromium on robins, however the risk is small and would likely diminish with time as chromium levels continue to drop in sewage sludge. The impact of copper on plant health arising from pellet use merits investigation and may be useful in establishing appropriate pellet application rates. The federal Minister of Agriculture and Agri-Food is requested to develop standards for maximum permissible levels of chromium and copper in biosolids pellets and for all fertilizers, as regulated through the federal Fertilizers Act.

If the City proceeds with reconstructing the pelletizer, more attention needs to be directed at the range of potential markets for pellet uses. There is benefit in developing a phased-in approach to marketing Toronto pellets that addresses public concern with their use for food crops. It is recommended that the initial marketing of pellets focuses on demonstrating successful use of pellets for horticulture, forestry and land reclamation applications prior to making pellets available for the home retail market in Toronto.

Conclusion:

Based on the biosolids pellets review study, there is no evidence to date that microbiological or chemical concerns are sufficiently significant to preclude the beneficial use of pellets for agricultural or horticultural purposes. However, a number of important recommendations are provided in Appendix A of this report need to be addressed if the City proceeds with reconstructing the pelletizer and developing markets for pellets within the City and beyond. In addition, it is recommended that the initial marketing of pellets focuses on demonstrating successful use of pellets for horticulture, forestry or land reclamation applications prior to making pellets available to the home retail market.

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List of Attachments:

Appendix A: Detailed Recommendations for the Commissioner of Works and Emergency Services Regarding Biosolids Pellets

Appendix B: Overview of the Toronto Biosolids Pellet Study

Appendix A
Detailed Recommendations for the Commissioner
of Works and Emergency Services Regarding Biosolids Pellets

It is recommended that if the City proceeds with reconstructing the pelletizer plant and developing markets for pellets within the City and beyond, the Commissioner of Works and Emergency Services:

(a) conduct follow-up monitoring of the pelletizer, or a pelletizer of similar design in operation, to confirm the effectiveness of the pelletizing process, including aspects such as process time, temperature and humidity;

(b) monitor the levels of metals, polychlorinated biphenyls, dioxins and furans in pellets and conduct trend analysis periodically to ensure that the quality of the pellets is maintained or continues to be improved through effective enforcement of the Toronto Sewer Use By-law;

(c) in consultation with the Medical Officer of Health, assess the feasibility of extending the routine monitoring program to include additional organic compounds and other unregulated metals, in particular those identified in this report; and once adequate data are available, consider the need to evaluate the significance of their impacts on human health and the environment;

(d) conduct testing for more suitable indicator bacteria and phages, by measuring reductions as a result of the pelletization process, until a sufficient history confirms the suitability of monitoring representative parameters and moisture content to ensure pellet quality. The testing should also be done at the time of pellet distribution to provide additional assurance for minimal risk from microbial agents;

(e) develop a contingency plan for unforeseeable events that may result in the production of pellets that are unsafe for planned uses, such as pelletizer malfunctioning or pellets not meeting specification. The contingency plan should include an alert system which serves as a trigger for specific actions in a timely manner to halt product distribution;

(f) conduct a field test on the potential for pathogen regrowth in the soil at the time of pellet use;

(g) conduct a review of storage issues for pellets, including the potential for pathogen and microbial regrowth and smouldering, and put into place the necessary precautionary measures prior to restarting pelletization of biosolids in Toronto;

(h) market pellets as a product only after the pelletization facility can achieve pellets of intended quality, approximately 3 mm in size and a solid content of 97% (3% water content);

(i) include precautions instructions on the label on how to properly store the pellets, including advice on preventing access to pellets by young children;

(j) avoid the use of pellets on lawns and park turf with extensive patches of bare soil where pellets might become accessible to young children, until such time as suitable indicator bacteria and phages confirms the absence of microbiological risk from accidental ingestion of pellets;

(k) conduct, in consultation with the Commissioner of Economic Development, Culture and Tourism, controlled field tests to provide added assurance that the pellets break down in a timely fashion to be useful as a soil amendment and fertilizer;

(l) conduct, in consultation with the Commissioner of Economic Development, Culture and Tourism, controlled field tests to monitor concentrations of the 'entities of concern' (identified in the Technical Summary) in pellet-amended soils over time in the park to confirm the results of the modelling exercise;

(m) consult with the Ontario Ministry of the Environment to explore non-agricultural uses for the pellets in Ontario;

(n) submit a proposal to the Minister of the Environment and the Minister of Agriculture and Food requesting that Section 97.(0.1) of Regulation 267/03 be amended to permit land application of further processed biosolids pellets to golf courses in Toronto; and

(o) focus initial marketing of pellets on demonstrating their successful use in horticultural, forestry or land applications prior to making pellets available to the home retail market.

Appendix B
Overview of the Toronto Biosolids Pellet Study

The purpose of the biosolids study was to provide a quantitative assessment of the health risks associated with different options for using biosolids pellets within Toronto. The study examined risks associated with pellet application: (1) on City-owned property (such as part of a landfill topdressing material applied as the final landfill cover seeded to establish a vegetative cover); (2) on parkland (such as on City-owned parks and golf courses); and (3) on residential properties (e.g. on lawns, gardens, vegetable growing beds).

The technical report "The Biosolids Pellet Review Study: Human Health and Ecological Risk Assessment" was prepared for Toronto Public Health by Jacques Whitford Environment Limited under the direction of a project team made up of staff from Toronto Public Health and experts from the academic sector. The study has benefited from advice from a Project Advisory Committee that included representatives from the Ontario Ministry of the Environment, Ontario Ministry of Health and Long Term Care, Ontario Ministry of Agriculture and Food, Toronto Public Health, Toronto Works and Emergency Services, Toronto Parks and Recreation, Ontario Federation of Agriculture, Rural Ontario Municipal Association, Canadian Infectious Diseases Society, Sierra Club, and the Implementation Compliance and Monitoring Committee. The Project Advisory Committee had input on the terms of reference for the study, selection of consultants through the request for proposals (RFP) process, assessment scenarios and interpretation of results. To ensure that the methodologies, analysis and interpretation of results meet the necessary scientific rigor, the technical report has been peer reviewed by four international experts from Canada and the United States.

The results of the full technical study have been incorporated into a technical summary report by public health staff. The summary report "Human Health and Ecological Assessment of Toronto Biosolids Pellets - Technical Summary" is available on the public health website (www.toronto.ca/health/hphe/waste/biosolids.htm). The full technical report prepared by Jacques Whitford Environment Limited is also available on the public health website, given the strong interest by municipalities across Canada for this type of research. While some municipalities have conducted a review of the international literature as it relates to land application of biosolids, the value of the current study is that it goes well beyond a literature review and provides a quantitative and qualitative assessment of risk based on the actual quality of Toronto's biosolids products.

(1) Agricultural and Horticultural Value of Biosolids

The nutrient value and organic matter content of biosolids make them potentially useful as a fertilizer and soil amendment. Biosolids are products of the sewage treatment process, which consists of a combination of physical, chemical and biological processes. The solids remaining after anaerobic digestion of sewage sludge are dewatered to produce biosolids cake (30% solid, 70% water). Pathogen content is reduced during the treatment processes. Biosolids cake can be further processed through heat drying to produce biosolids pellets. Biosolids cake and pellets are then available for landfilling, incineration or land application.

The pelletizer plant that was installed at the ABTP produced pellets through an indirect heating process that coats a nucleus of dry biosolids with wet biosolids. The pellets are exposed to high heat and controlled dryer times. The dryer can produce pellets approximately 3 mm in diameter and 97% solid, with 3% water content. Currently the Toronto pelletizer is out of service following a fire at the facility in August 2003.

Organic matter, such as that arising from sewage treatment plants, can potentially have agricultural or horticultural value in two ways: (1) as a fertilizer if it contains sufficient essential elements for plant growth; and (2) as a soil amendment that improves the physical structure of soil. Biosolids cake is used widely in North America as a fertilizer and soil amendment on agricultural lands. Compared with biosolids cake, biosolids pellets have greatly reduced pathogen content, assuming the pelletizer is functioning optimally and is meeting all expected provincial standards.

Toronto’s biosolids contain appreciable concentrations of many of the fifteen elements essential for plant growth, but not much potassium. The pellets could potentially be used as soil amendments, as well as general-purpose lawn and garden fertilizers if they are blended with potassium and water-soluble nitrogen to boost the content of plant nutrients. However, before this option becomes viable, further work is required by WES to establish the release rates of the organic matter and nutrients to determine the actual usefulness and suitability of the pellets for different applications.

Biosolids are a potentially valuable resource that merit further study by WES as to marketing opportunities. The focus of the biosolids study by Toronto Public Health is confined to assessment of the chemical and biological risk associated with pellet use in Toronto.

(2) Health Risk from Pellet Use

The risks to human health were assessed through a quantitative risk assessment for metals and key organic chemicals present or potentially present in Toronto biosolids. To assess biological risk, the study examined the effectiveness of the pelletization process in destroying biological agents of potential concern, such as indicator bacteria, enteric viruses and parasitic pathogens.

(a) Chemical Risk

The assessment of health risk was made possible by the large volume of data collected by WES since 1978 on the levels of chemicals in Toronto’s biosolids. There have been improvements over the years in sewage treatment efficiency, changes in the type of industrial operations in Toronto and greater control over discharges to the sewer system. The levels of metals in Toronto biosolids show an overall downward trend since 1978. This downward trend was further enhanced with the enactment of a revised Sewer Use By-law in July 2000 which introduced more stringent discharge limits for contaminants into sewers, and which required industries to submit pollution prevention plans since July 2001. The levels of arsenic, chromium, nickel, lead, zinc and mercury in Toronto biosolids have dropped since the revised Sewer Use By-law was implemented.

The land application of Toronto's biosolids first began in 1995. The risk assessment was based on sludge cake data from 1996 to 2003 because it was most representative of current biosolids quality. Using these and auxiliary data, the health risks associated with exposure to eleven regulated metals (arsenic, cadmium, cobalt, chromium, copper, mercury, molybdenum, nickel, lead, selenium and zinc) polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (dioxins) and polychlorinated dibenzofurans (furans) were evaluated for the various options for using biosolids pellets within Toronto.

Cake data were used in the risk assessment because the cake data set was more complete than the pellet data set. Data on pellets was collected for only a relatively short time period after September 2002 and prior to the fire at the pellet plant. Use of cake data tends to overestimate rather than underestimate chemical concentrations in pellets, especially for the more volatile chemicals. This is because the chemical contents in biosolids are measured from liquid samples and reported on a dry weight basis as required by the MOE. As a result, it is reasonable to assume that the actual health risk from chemical exposures through pellet use is even less than reported in the risk assessment.

Health risks were estimated for landfill and park workers applying pellets, residents (adult and young children) who come into contact with recreational spaces (e.g. parks, golf courses, gardens) on which pellets are applied, and residents (adults and young children) exposed to pellet use on home lawns and backyard gardens. Among the residents, young children between the ages of 7 months and 5 years represent those likely to experience the highest exposure due to their low body weight, higher metabolic rate and hand-to-mouth activity. Cancer risk is evaluated for exposure over a lifetime.

Ingestion of pellets, pellet-amended soils, inhalation of dust and vapour, and dermal contact were considered for exposure estimation for pellet use on park turf and lawns. Ingestion of vegetables and fruits grown on pellet-amended soil was an additional exposure pathway considered in the home garden scenario. Although pellets would not be readily available for children present on healthy lawns with thick turf, they are more accessible if spread on lawns with extensive patches of bare soil. Therefore, the exposure calculation took into consideration the scenario that children under 5 years old might ingest pellets that they pick up from bare soil surfaces.

The risk assessment was based on the assumption that pellets would be applied for 25 years, which is the lifetime of the pelletizer. To take into consideration that some people might overapply pellets, twice the maximum recommended application rate (5.4 tonnes per hectare per year) was used to calculate the levels of pollutants in pellet-amended soil, garden produce, dust and vapour in the air after 25 years of pellet use. The risk assessment was based on the upper-end contaminant levels expected after ongoing pellet use over a 25-year period.

The method used to assess the health risks to residents and workers is based on comparing the calculated predicted exposures to a given chemical from all the likely exposure pathways, and comparing these to scientifically-based health benchmarks below which there would be no or negligible health risks. In the case of substances that are not carcinogenic, the health benchmark is the level below which no health risk is anticipated. In the case of carcinogens, the benchmark of negligible risk used by various jurisdictions typically varies from a one-in-ten thousand to a one-in-one million increased risk of cancer over a lifetime. Toronto Public Health typically adopts the more health protective one-in-a-million cancer risk level. Health benchmarks used in the biosolids study were adopted from published values by reputable regulatory agencies such as Health Canada, USEPA and MOE after a review of their scientific basis. The results from the risk assessment based on 25 years of pellet use in Toronto indicate that potential exposure to arsenic, cadmium, cobalt, chromium, copper, mercury, molybdenum, nickel, lead, selenium, zinc, PCBs, dioxins and furans are below the health benchmarks for non-cancer effects, and thus are not expected to result in adverse non-cancer effects.

Of the substances evaluated, arsenic, cadmium, PCBs, dioxins and furans are known or probable human carcinogens, in addition to having the potential to have non-cancer adverse effects at levels higher than those associated with pellet use. The results from the risk assessment show that exposure to cadmium, PCBs, dioxins and furans for a lifetime as a result of pellet use would increase cancer risk by less than one-in-a-million new cases, and hence are considered to be of negligible health risk.

In the case of arsenic, the cancer risk for lifetime exposure resulting from ingestion/dermal exposure after 25 years of pellet use in the home environment was estimated to be five-in-a-million. This risk is below the Health Canada benchmark of negligible risk of one in-a-hundred thousand. Ingestion of home-grown fruits and vegetables contributes about 80% of the total lifetime incremental cancer risk while risk from exposure due to pellet use only on lawns makes up about 20%. The risk from lawn use alone is about one-in-a-million and hence of negligible health risk.

The predicted cancer risk for arsenic exposure is likely overstated in the risk assessment because the many assumptions used in the calculations tend to overestimate the risk, including the use of cake data for the assessment. The arsenic concentration is much lower in pellets than in cakes and is actually similar to the background soil concentration in Toronto. Furthermore, the arsenic levels in Toronto biosolids are decreasing overtime, particularly since the enactment of the improved Toronto Sewer Use By-law in July 2000. If the trend continues, the actual arsenic concentration in the pellet-amended soil after 25 years of application would likely be lower than the value calculated in the risk assessment study. Finally, many fertilizers in existing use contain traces of arsenic. It is noteworthy that the levels of arsenic in the biosolids pellets are below allowable limits for arsenic in fertilizers sold in Canada. Given these observations, it is reasonable to assume that the cancer risk from arsenic associated with prolonged pellet use is very low and would be of minimal health consequence.

Since health risk was calculated using the estimated soil concentrations after 25 years of pellet use, if operation and sale of pellets were to continue beyond the 25-year period, further review would be required at that time. A field study to monitor annually the change in soil concentration (e.g. in a park) is recommended to confirm the results of the modelling exercise.

(b) Biological Risk

The assessment of biological risks is more difficult than assessing chemical risks for which there are well-developed guidelines on how to conduct the assessment and health benchmarks against which to assess risk. There are no established guidelines for conducting assessments of biological risks from environmental exposure to biological agents and no clear definition for acceptability as to what level of exposure constitutes a health risk and what level is of negligible or no risk. The science of assessing biological risks is still under development by the scientific community. Consequently the risk from exposure to pathogens as a result of pellet use has not been calculated. Rather this study evaluated the effectiveness of the pelletization process in destroying biological agents of potential concern.

In the United States, biosolids are classified based on certain quality characteristics. To qualify for Class A designation, biosolids must meet specific process, pathogen content and monitoring requirements. The objective is to reduce pathogen content to below detection limits for Salmonella sp., enteric viruses and viable helminth ova (a parasite pathogen). The microbial agents must be measured at the time the biosolids are used or disposed and prepared for distribution. Processes that involve heat treatment must also meet specific time-temperature requirements. The pelletizer manufacturer asserts that the pelletization process at ABTP meets the United States Environmental Protection Agency (USEPA) requirement for Class A biosolids. If the Toronto pelletizer is reconstructed and meets the operating conditions required for Class A biosolids, the pellets can be distributed in the United States without restriction since they also meet the USEPA chemical pollutant concentration limits.

The scientific literature suggests that a minimum process time of 60 to 90 minutes at a temperature of 80°C is needed to effectively destroy most pathogens and qualify the biosolids as Class A. The process information and limited analytical data available suggest that the biosolids pellets from ABTP were likely of similar quality to Class A biosolids. However, no confirmatory testing is known to have been undertaken to validate the pellet temperature, drying time and humidity achieved by the ABTP pelletizer. Follow-up monitoring of the pelletizer or a pelletizer of similar design in operation should be used to verify these operating conditions, and confirm the effectiveness of the process. The pelletizer process should be maintained without attempting to hasten production of pellets. A mechanism has to be in place that provides assurance that the necessary processing is taking place at all times when the pelletizer is in operation. A contingency plan and emergency procedures to address pelletizer malfunction and related issues should be part of the overall operating program for producing biosolids pellets.

Although pelletization appears to provide the conditions for effective destruction of microorganisms, additional monitoring is needed to confirm this because the testing of biological agents is limited to date. This could be done by routine monitoring for selected bacteria and phages. Faecal coliform (the most common indicator organism monitored) is a suitable indicator organism for treatment efficiency, but may not be ideal as an indicator for public health hazard. Some pathogens are hardier than faecal coliform. Phages are considered suitable indicators for the presence of human enteric viruses and as process indicators for bacteria. The pellets should be routinely monitored for selected bacteria and phages by measuring reductions during treatment until a sufficient history of the process confirms the suitability of monitoring only certain process parameters (e.g. temperature and time) and a smaller number of indicator microorganisms at the time of pellet distribution.

One potential risk from biosolids aerosols (airborne particles) arises from endotoxins on the outer cell wall of some bacteria, whether they are pathogens or not. Airborne endotoxins can exacerbate existing allergy and asthma symptoms, thus increases the risk to infection. The pelletization process is unlikely to provide the needed conditions to destabilize the endotoxin. However, the dust fall from the pellets is expected to be low as long as the pellets remain dry and would likely not be a concern for the general public. For workers routinely handling large quantities of pellets, a similar degree of care generally used for handling fertilizers would be reasonable to minimize potential exposures during handling.

If pellets are exposed to moisture or water, there may be a potential for the pellets to break down more readily into dust upon handling. A relative moisture content around 9% was reported to be sufficient to initiate microbial activity. Such activity can occur if drying is incomplete. Therefore it is important that the pelletizer is operated properly and that commercial distribution of pellets takes place only after the pelletizer can consistently achieve pellets of the intended quality (3% water content at most). Routine monitoring of moisture content is advisable. Rewetting biosolids pellets prior to land spreading could also permit some pathogen regrowth. The biological activity initiated can then contribute to the self-heating phenomenon that is sometimes observed. Dry storage conditions would prevent this type of problem. Issues regarding storage and handling need to be addressed by WES to reduce the chance of microbial regrowth and smouldering prior to restarting pelletization of biosolids at ABTP. Pathogen regrowth has also been observed following land application following rainfall.

It is possible that the pelletization process may not have deactivated some biological agents. While pellets spread on lawns with well-established turf are not readily available to children less than 5 years old, those left on patches of bare soil can be accessible. The available methods and information are not adequate to quantify risks to these children in contracting infectious diseases from ingestion of pellets while playing in the park and on lawns at home.

(3) Ecological Risk from Pellet Use

The assessment of ecological risk was undertaken to evaluate the likelihood of adverse effects for a set of indicator ecological (non-human) receptors that are important to humans. These receptors are considered representative of species in the Toronto area. The assessment considered the three environments for pellet use: landfill topdressing; recreational green spaces (parks and golf courses); and residential properties.

(a) Plants and Soil Organisms

A screening level assessment was conducted with respect to plants and soil organisms. The levels that may accumulate in the soil after 25 years of pellet application were compared to the Canadian Council of Ministers of the Environment (CCME) and MOE ecotoxicity criteria for plants and soil organisms. As a result of this assessment, no risk to plants or soil organisms from pellet use are expected from arsenic, cadmium, cobalt, chromium, mercury, molybdenum, nickel, lead, selenium, zinc, PCBs, dioxins and furans. Levels of copper were higher than both the MOE toxicity value and CCME criteria.

The screening assessment is not adequate to conclude whether or not adverse effects may actually occur. It is useful only for identifying areas that need further analysis and areas that do not. Therefore, to confirm whether plants or soil organisms would be at risk from copper due to pellet application on lawns, gardens or City lands, more detailed evaluation is needed. To facilitate this evaluation, more comprehensive studies, including laboratory-based research and field studies, are needed to address the potential bioavailability, phytotoxicity and/or ecotoxicity resulting from long-term use of pellets in urban parks and residential properties.

(b) Wildlife and Pets

A limited quantitative ecological assessment was conducted for wildlife and pets, using an assessment framework similar to that used for human health. Representative species from different levels in the food chain were selected for assessment. Receptors include: animals that feed on vegetation only (vole); animals that feed on other smaller animals (masked shrew); animals that feed on both smaller animals and vegetation (red fox); birds that eat worms only (American robins); and birds of prey (red-tailed hawk). The most important exposure pathway for wildlife and pets is ingestion, including ingestion of plants and prey species that have accumulated chemicals from the soil, as well as soil ingestion as a result of feeding and grooming.

The risk assessment indicates that for cats and dogs potentially exposed to pellets, the calculated associated exposure to arsenic, cadmium, chromium, cobalt, copper, mercury, molybdenum, nickel, lead, selenium, zinc, PCBs, dioxins and furans would all be below health benchmarks. It is therefore unlikely that the use of biosolids pellets around the home or parks would pose a danger to pets.

For the wildlife indicator species – vole, masked shrew, red fox and red-tailed hawk - the risk assessment indicates that exposure to pellets and associated chemicals would be below levels associated with adverse effects in relation to survival or reproduction. In the case of the American robin, only one chemical pollutant, chromium, was associated with some risk, given that robins eat mainly worms, which in turn could be exposed to pellets. The American robin is considered to be more sensitive than other bird species in Toronto, so that an elevated risk for the American robin is not expected to indicate a potential risk to other bird species.

The chromium levels in Toronto biosolids are decreasing over time, particularly since the enactment of the more stringent Sewer Use By-law in July 2000. If this trend continues, the actual chromium concentrations in pellet-amended soil after 25 years of application would likely be considerably lower than the value used in the current risk assessment. Furthermore, it is likely that the current risk assessment overestimates the actual risk to robins since the bioavailability of chromium in soil is likely less than the 100% assumed in the assessment. Taken together, these observations suggest that the risk to robins is not significant, and would likely diminish with time.

(4) Emerging Issues

Some new concerns have arisen in recent years related to the land application of biosolids. Some concerns are due to newly detected chemicals in sewage or biosolids worldwide. Other concerns come about because of new evidence indicating potential adverse effects for certain substances that could be present in the sewage. For example, the effect of low level exposure to endocrine disruptors is an emerging issue that continues to be monitored by the scientific community.

Other chemicals of scientific and public interest are flame retardants (e.g. polybrominated diphenyl ethers (PBDEs)), linear alkylbenzene sulphonates, pharmaceuticals, radioactive materials, other unregulated metals, and endocrine disruptors such as phthalates, alkylphenol ethoxylates and their metabolites alkylphenols. A preliminary review of the issues suggests that the risk to humans may not be substantial, however, the characterization of these substances for their potential presence in biosolids or pellets is not well developed. For this reason, these chemicals are not included in routine biosolids monitoring programs. Toronto can reduce the possible risk from exposure to these substances via land application by improving the quality of the biosolids through continual update and enforcement of the Sewer Use By-law.

The detection of antibiotics in wastewater arising from sewage treatment plants worldwide raises concern about the possibility of proliferation of drug-resistant strains of bacteria in biosolids and the environment. The National Research Council reviewed this issue in 2002 and concluded that land application of biosolids would not have any substantial potential to alter the prevalence of antibiotic resistance among pathogenic microbial agents. Health Canada, which is responsible for regulating pharmaceuticals, is considering the development of a ‘cradle to grave’ approach to dealing with pharmaceuticals, thereby greatly limiting their entry into the environment.

Prions are infectious biological agents that are not living organisms. Examples of illnesses that have arisen from prions are Creutzfeldt-Jakob disease in humans or bovine spongiform encephalopathy (mad cow disease) in animals. There is no evidence from other jurisdictions or the scientific literature for the transmission of prions from diseased animals through their feces or urine, however, blood components have been found to carry infectivity. For example, blood transfusion has been demonstrated to transmit prion disease in experimental animals, and was suspected but not proven in two human cases. The potential risk for exposure to prions through Toronto’s biosolids pellets is very low, in large part because there is no known source of prions. Nonetheless, precautionary measures should be taken to prevent biosolids from potentially acting as a vehicle for transmission of prion diseases. Consequently, it is recommended that the discharge of untreated blood and blood products into sewers be restricted. Policies regarding abattoir (slaughterhouse) operations similar to those in the United Kingdom could be adopted in Ontario. These include the placement of fine screens in abattoir drains to prevent prion-containing tissues from entering the sewer system.

The possible public perception that pellets are associated with an odour may affect public acceptance of pellet use. Odour detection is very subjective and varies considerably across the population. Although biosolids pellets would be at the low end of a subjective measurement scale of odour unpleasantness, individual tolerance and sensitivity to odours will influence public acceptance.

(5) Regulations and Monitoring

Biosolids sold as fertilizers or soil supplements for non-agricultural uses in Ontario are regulated by the federal Fertilizers Act, which specifies standards for labelling, registration and product quality, including the level of metals in the product. Since the Fertilizers Act has no monitoring requirement regarding product use, it is at the users' discretion to adhere to the instructions on the label.

The pellets produced by the City of Toronto contain 10% or less total nitrogen, available phosphorus and soluble potash. Because of this, the pellets will be considered "non-agricultural source material" under the Ontario Nutrient Management Act (NMA), even if they are sold. The Nutrient Management Regulation 267/03 prohibits the application of a non-agricultural source material to golf courses. Furthermore, like pellets that are not sold but given away, Toronto pellets are regulated by the same Ontario regulations as the biosolids cakes (see next section) when applied on agricultural land. The Ontario regulatory framework provides for non-agricultural uses of biosolids, although the regulatory processes governing some of these uses, such as reclamation of mine tailing, have not been worked out.

(6) Toronto Biosolids Cake

The application of biosolids cake on agricultural land is regulated in Ontario through the Environmental Protection Act and Regulation 367/03 of the Nutrient Management Act. Municipal biosolids cakes are considered "non-agricultural source material" under the Act and are subject to the MOE "Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land". The Guidelines specify general rules for application of biosolids regarding application rates and quality standards for the eleven inorganic elements. The maximum soil criteria for the eleven inorganic elements are background based. Since soil testing is often required when applying for a Certificate of Approval for each application site, it is unlikely that these soil criteria would be exceeded. Therefore, the risks to humans, farm animals and wildlife from exposure to the eleven regulated metals as a result of land application of Toronto biosolids cakes on agricultural land are expected to be minimal.

Although biosolids cakes are treated sewage sludge with reduced pathogen content, they contain much higher levels of pathogens than pellets. To reduce the risk of infection from biosolids cake through land application, the MOE biosolids Guidelines require site restrictions for land application. The Guidelines specify separation distances from surface water, wells and residences. The Guidelines also specify waiting periods. Site-specific terms and conditions are contained in the Certificate of Approval that must be obtained for each application site. While there are anecdotal claims of illness associated with land application of biosolids cake in North America, the review of epidemiological evidence for health effects has yielded mixed results. Most studies were either unable to demonstrate increased human health effects, or found certain health effects to be somewhat increased but not significantly so. Some studies did find a significantly higher prevalence of gastrointestinal symptoms or headaches among sewage treatment plant workers and slightly higher rates of viral infection among farm and resident populations.

The MOE is responsible for ensuring that the land application of biosolids cakes is done in a safe manner. The MOE is sponsoring two major multi-year studies to deal with concerns about pathogens in biosolids. One study examines the movement of pathogens in soil following the application of biosolids. The other study examines the fate and level of pathogens resulting from the application of cake and liquid biosolids on farm fields with tile drains. These studies are scheduled for completion in 2006. The MOE is monitoring research initiatives elsewhere regarding the measurement of airborne pathogen levels around land application sites and will consider doing the same to address public concerns regarding bioaerosols (biological agents that become airborne). The MOE is also conducting an odour study, seeking to establish a benchmark for "normal farming practices," and examining the standardized odour testing procedures developed in Quebec. In addition, the MOE has been actively promoting and developing best management practices for the province.

It would be beneficial for the MOE to conduct a review study regarding the use of biosolids cakes, including a quantitative assessment of human health and ecological risks, similar to Toronto Public Health's study on pellets. Furthermore, it is recommended that the Ministry of Health and Long Term Care conduct a health study regarding the use of biosolids cakes, in consultation with the MOE.

(7) Potential Uses of Toronto Biosolids

Toronto Public Health's biosolids review study examined the health and ecological risk associated with three different use scenarios. These scenarios were selected for scientific purposes to identify the higher risk exposure scenarios, such as assessing risks to young children (given their high hand-to-mouth activity) and those of workers applying pellets (given the opportunity for frequent contact with pellets). Many other scenarios for using biosolids are possible, including: as inputs to facilities producing fertilizers; for horticultural applications such as in plant nurseries; for forestry applications; to enhance turf and other plants in greenspaces; to reclaim damaged or derelict urban lands; to reclaim damaged soil such as with disposal of mine tailings; and as landfill cover.

If the City proceeds with reconstructing the pelletizer, more attention needs to be directed at the range of potential markets for pellet uses. There is benefit in developing a phased-in approach to marketing Toronto pellets that addresses public concern with their use for food crops. It is recommended that the initial marketing of pellets focuses on demonstrating successful use of pellets for horticulture, forestry and land reclamation applications prior to making pellets available for the home retail market in Toronto.

<u>Conclusion</u>:

Based on the biosolids review study, there is no evidence to date that microbiological or chemical concerns are sufficiently significant to preclude the beneficial use of pellets for agricultural or horticultural purposes. However, a number of important recommendations are provided in this report that need to be addressed if the City proceeds with reconstructing the pelletizer and developing markets for pellet uses within the City and beyond. In addition, it is recommended that the initial marketing of pellets focuses on demonstrating successful use of pellets for horticulture, forestry or land reclamation applications prior to making pellets available to the home retail market.

Human Health and Ecological Assessment of Toronto Biosolids Pellets

Technical Summary

Dr. David McKeown
Medical Officer of Health

November 2004

TORONTO Public Health

Reference: Toronto Public Health. *Human Health and Ecological Assessment of Toronto Biosolids Pellets - Technical Summary*. Toronto, Ontario: November 2004.

Author: Angela Li-Muller, Ph.D.

Acknowledgements: Special thanks to Dr. Donald Cole (University of Toronto), Dr. Michael Goss (University of Guelph), Dr. Beverley Hale (University of Guelph), Ms. Cecile Willert (Jacques Whitford Environment), and the following staff from Toronto Public Health: Dr. Monica Campbell, Ms. Karen Clark, Mr. Fred Goettler, Mr. Ronald Macfarlane and Ms. Angie Pieroni for their expert advice and assistance in preparing this report.

Technical Basis: This report incorporates information and highlights from the technical study prepared for Toronto Public Health by Jacques Whitford Environment Limited entitled *Biosolids Pellet Review study: Human Health and Ecological Risk Assessment*

Distribution: Both the summary and technical reports are available on the website at: www.toronto.ca/health/

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Preface

This report incorporates information and highlights from the technical study prepared for Toronto Public Health by Jacques Whitford Environment Limited entitled *Biosolids Pellet Review study: Human Health and Ecological Risk Assessment.* The report arises from the environmental assessment of the Ashbridges Bay Treatment Plant and responds to community requests to the City to prepare a study reviewing the use of biosolids.

The overall objectives of the study were to:

- improve knowledge and understanding about biosolids pellets and related issues;
- provide information to assist in developing appropriate management practices for pellet use in the City of Toronto; and,
- provide practical and scientific information to address public concerns related to pellets.

In order to ensure that the study was carried out in a scientifically sound manner, Toronto Public Health has set up a Project Team with relevant expertise to design, direct and oversee the study. In addition, Toronto Public Health asked experts from Canada and the United States to peer review the study report and findings.

A Project Advisory Committee advised the project team on the issues that needed to be addressed and areas of concern relevant to the study. The Project Advisory Committee consisted of community members, representatives from the Ontario Ministry of the Environment, Ontario Ministry of Health and Long Term Care, Ontario Ministry of Agriculture and Food, City of Toronto Works and Emergency Services, Toronto Parks and Recreation, Toronto Public Health, Ontario Federation of Agriculture, Rural Ontario Municipal Association, and Canadian Infectious Diseases Society.

Project Team

Name	Affiliation	Expertise
Dr. Angela Li-Muller (Project Lead)	Toronto Public Health	Toxicology, human health assessment, quantitative risk assessment, biosolids-related health and environmental issues
Karen Clark	Toronto Public Health	Legal, environmental health policy, biosolids-related legal and policy issues
Dr. Donald Cole	University of Toronto	Community medicine, epidemiology, environmental health intervention, biosolids-related health issues
Dr. Michael Goss	University of Guelph	Safe application of organic materials (including biosolids) to agricultural land, prevention of contaminants (e.g. nitrate, pathogen) polluting water resources, transport of contaminant to water sources, biosolids issues
Dr. Beverley Hale	University of Guelph	Soil science, contaminant uptake into plants, biosolids-related environmental and ecological issues

Consulting Team

Name	Affiliation	Expertise
Cecile Willert, P. Eng.	Jacques Whitford Environment	Human health and ecological risk assessment, toxicology, hazard assessment
Dr. Chris Ollson	Jacques Whitford Environment	Human health and ecological risk assessment
Erik Apedaile, P.Ag.	Apedaile Environmental Management	Agronomy, biosolids management issues
Rena Chung	Jacques Whitford Environment	Human and ecological risk assessment, toxicology
Siobhan Sutherland	Jacques Whitford Environment	Risk assessment
Ian Collins	Jacques Whitford Environment	Risk assessment
Dr. Malcolm Stephenson	Jacques Whitford Environment	Ecological risk assessment
Susan Springthorpe	Centre For Research on Environmental Microbiology University of Ottawa	Quantitative environmental microbiology
Dr. Syed A. Sattar	Centre for Research on Environmental Microbiology University of Ottawa	Microbiology related to biosolids

External Peer Reviewers

Name	Affiliation	Sections reviewed
Ms. Sanya Petrovic	Risk Assessor/Toxicologist Health Canada	Human health risk: chemical and biological agents
Ms. Ellen Harrison	Director, Cornell Waste Management Institute Cornell University	Human health risk: chemical and biological agents
Dr. Tim Sly	Professor, School of Occupational & Public Health Ryerson University	Human health risk: biological agents
Dr. Rebecca A. Efroymson	Oak Ridge National Laboratory Environmental Sciences Division	Ecological risk

Current Project Advisory Committee Members

Name	Affiliation
Dr. Monica Campbell (Chair)	Toronto Public Health
Mr. Ronald Macfarlane (Alternate Chair)	Toronto Public Health
Ms. Nancy Martins	Toronto Works and Emergency Services
Ms. Karey Shinn	Implementation and Compliance Monitoring Committee (ICMC)
Ms. Karen Buck	ICMC
Ms. Maureen Reilly	Sierra Club
Mr. David Armitage	Ontario Federation of Agriculture
Mr. William Tracy	CUPE Local 416
Dr. Brian Gibson	University of Toronto
Mr. Larry Schut	Ontario Ministry of Agriculture and Food
Dr. Gloria Rachamin	Ontario Ministry of Health and Long-Term Care
Mr. Tony Ho	Ontario Ministry of the Environment
Mr. Bill Semeniuk	Association of Municipality of Ontario, Rural Ontario Municipal Association
Mr. Arthur Beauregard	Toronto Parks & Recreation
Dr. Coleman Rotstein	Canadian Infectious Diseases Society
Mr. Mark Rupke	Toronto Works & Emergency Services
Ms. Nancy Fleming	Toronto Works & Emergency Services
David Done*	ICMC

* Alternate Member

Summary of Findings

The results of the risk assessment for health and ecological risk for the three types of pellet use are summarized below. These uses include the use of pellets on City-owned recreational areas such as parks and golf courses, home use on lawns and gardens, and use as part of a landfill topdressing mixture.

The conclusions and recommendations arising from the report can be found on page 43 and 45, respectively.

Human Health Risks from Non-Cancer Effects

The potential exposures to the substances studied, including arsenic, cadmium, cobalt, chromium III, mercury, molybdenum, nickel, lead, PCBs, dioxins and furans are below the health benchmark, and are not expected to result in adverse non-cancer effects. One way to estimate if exposure levels are of concern is to calculate the hazard quotient, which is a ratio that compares estimated exposure levels against the health benchmark. The hazard quotient for the inhalation pathway and the combined oral and dermal exposure pathways from exposure after 25 years of pellet application were below the MOE's benchmark of 0.2 for all the chemicals evaluated under all exposure scenarios considered.

Human Health Risks from Cancer Effects

Of the substances evaluated in the study, arsenic, cadmium, PCBs, dioxins and furans are known or probable human carcinogens. The exposure ratios from lifetime exposure from pellet use to cadmium, PCBs, dioxins and furans were below one for all scenarios considered using Ontario Ministry of Environment (MOE) benchmark of negligible risk. This means that exposure to these substances for a lifetime as a result of pellet use would increase cancer risk by less than one in one million.

In the case of arsenic, the cancer risk for the lifetime receptor resulting from ingestion/dermal exposure after 25 years of pellet use in the home environment was estimated to be five in a million. However, the risk estimation assumes that pellets are applied at double the maximum recommended application rate (5.4 tonnes per hectare per year as opposed to 2.7 tonnes per hectare). The risk is below the Health Canada benchmark of negligible risk of one in a hundred thousand. Ingestion of fruits and vegetables grown in pellet-amended soil constitutes 79% of the total lifetime incremental cancer risk while risk from using pellets on the lawn

alone constitutes about 20%. The risk from lawn use alone is about one in a million and meets the MOE benchmark of negligible risk.

To understand the implication of the exposure ratio estimate for arsenic for the Home Use Scenario, several factors should be considered including the following:

- The calculated risk was within the range of uncertainty generally associated with risk assessments; the many assumptions used in the calculations tend to overestimate the risk, including use of cake data for the assessment. The arsenic concentration is much lower in pellets than in cakes and is actually similar to the background soil concentration in Toronto. The study used biosolids cake data because the pellet data are limited.
- The arsenic levels in Toronto biosolids are decreasing over time, particularly following the enactment of the Toronto revised Sewer Use By-law in July 2000. If the current trend in reduction continues, the actual arsenic concentration in the pellet-amended soil after 25 years of application will likely be lower than the value used in the assessment.
- Many fertilizers currently used in the urban environment contain traces of arsenic; the levels of arsenic in the biosolids pellets are below allowable limits for fertilizers.

Therefore, the report likely overstates the actual cancer risk for arsenic exposure.

Human Health Risk from Exposure to Biological Agents

There are no well-developed guidelines for conducting assessments of biological risks from environmental exposure to biological agents and no clear definition for acceptability. Since the science of quantifying such risks is under development, conclusions regarding the acceptability of pellet use based on potential biological risks cannot be made. The assessment was therefore limited to examining the potential for biological agents to be present in biosolids or to be destroyed in the pelletization process. The major findings are as follows:

- The pelletizer manufacturer asserts that the pelletization process at Ashbridges Bay Treatment Plant (ABTP) meets United States Environmental Protection Agency (USEPA) requirements for Class A biosolids.
- The process information and limited analytical data available suggest that the biosolids pellets from the ABTP pelletizer are likely of similar quality to Class A biosolids. This needs to be confirmed under full production conditions. Once the quality is shown to also meet the USEPA chemical pollutant concentration limits, they can be distributed in the United States without restriction.

- No known confirmatory testing has been undertaken to validate the temperature, residency times and humidity achieved by the pelletizer.
- Confirmatory testing of pellet quality with respect to biological entities is limited.
- The pelletization process may not deactivate some biological entities in the biosolids pellets. The chances of exposure to such entities increase with frequency and duration of handling, as well as quantities used. Therefore exposure would be greater for workers than for residents.
- Microbial activity can occur in the pellets if the drying is incomplete as a result of the pelletizer not being operated according to design specifications. Rewetting biosolids pellets prior to land spreading could also permit some pathogen regrowth. The microbial activity can then contribute to the self-heating phenomenon that is sometimes observed.
- Pellets spread on lawns and park turf with extensive patches of bare soil can be visible and therefore readily available to children less than 5 years old to pick up. The available methods and information are not adequate to quantify risks to children ingesting pellets while playing in the park and on the lawns at home.
- The potential risk of exposure to prions through pellet use is very low, even though pelletization processes may not effectively deactivate prions.

Ecological Risks

Plants and Soil Organisms

A preliminary screening was done for potential ecological effects on plants and soil organisms. Risks to plants or soil organisms are not anticipated when pellets were used in landfill topdressing. The levels that may accumulate in the top 5-cm of soil (parks, golf courses and lawns) after 25 years of pellet application were compared to Canadian Council of the Ministers of the Environment (CCME) and Ontario Ministry of the Environment (MOE) ecotoxicity criteria values for plants and soil organisms. The results included:

- No risks to plants or soil organisms were identified for arsenic, cadmium, cobalt, chromium III, mercury, molybdenum, nickel, lead, PCBs, dioxins and furans.
- The estimated concentrations of selenium and zinc were less than the corresponding MOE values but slightly higher than CCME ones. The results indicate that risk to plants or soil organisms due to selenium or zinc is unlikely.

- Levels of copper were estimated to be slightly higher than the MOE toxicity value and about four times higher than the CCME ecotoxicity value. Copper levels were also higher than CCME ecotoxicity values when pellets were assumed to be mixed within the top 15-cm of soil (gardens).

The qualitative screening assessment performed for plants and soil organisms is considered sufficient to identify areas where closer analysis may be warranted. The analysis is not sufficient to conclude whether or not adverse effects on plants or soil organisms may actually occur. Further evaluation using toxicity values based on plants most commonly found in Toronto parks and gardens, and including consideration of the potential for reduced bioavailability of metals in biosolids-amended soils, would be required to conclude whether or not plants or soil organisms may be at risk from copper in pellets applied to lawns, gardens or City lands.

Wildlife

The report assessed the potential impacts on wildlife by considering potential exposures to the meadow vole, masked shrew, raccoon, red fox, American robin, and red-tailed hawk. After 25 years of use, when pellets were incorporated into the top 5-cm of the soil, the following hazard quotients (ratios of estimated exposure levels to effect benchmarks) were estimated:

- Hazard quotients were less than one for the meadow vole, masked shrew, raccoon, red fox, and red-tailed hawk for all chemicals evaluated, indicating no adverse effect at the population level.
- Hazard quotients were less than one for the American robin exposure to arsenic, cadmium, cobalt, copper, mercury, molybdenum, nickel, lead, selenium, zinc, PCBs, dioxins and furans, indicating no adverse effect expected at the population level.
- The hazard quotient for the American robin exposure to chromium III was three.

Hazard quotients greater than one suggest that the exposures are above the benchmarks but do not necessarily imply a risk. The assumptions used in the calculations tend to overestimate the levels of exposure and therefore overstate the potential risks. For example, the assumptions did not include the consideration that robins migrate out of the Toronto area for approximately half a year. The assessment assumed that a robin would feed exclusively in areas where pellets were spread regularly, which is unlikely. Therefore, effects to robins are not expected. The American Robin is considered to be more sensitive than other bird species in Toronto because of its consumption of worms. The elevated hazard quotient of three estimated for the American Robin is not expected to indicate a potential risk to other bird species.

The chromium levels in the biosolids are decreasing over time in the recent years, a trend that can in part be attributed to the enactment of the Toronto revised Sewer Use By-law in 2000. If the trend continues, the actual chromium concentration in the pellet-amended soil after 25 years of application would likely be lower than the value used in the assessment. In addition, the bioavailability of chromium in soil is expected to be less than the 100% assumed in the assessment. Either of these factors alone would be sufficient to reduce the hazard quotient for robins to below one, indicating that no effect to robins is expected.

Pets

Potential risks to pets as individuals were quantitatively evaluated. The results were as follows:

- Hazard quotients (ratios of estimated exposure levels to effect benchmarks) were less than one for cats and dogs exposed to cadmium, chromium III, cobalt, copper, mercury, molybdenum, nickel, lead, selenium, zinc, and PCBs.
- The hazard quotient was less than one for dogs exposed to dioxins and furans.
- The hazard quotient for cats exposed to dioxins and furans, and for cats and dogs exposed to arsenic were estimated to be one.

The benchmarks for assessing potential risk from contaminant exposure to house cats and dogs are based on No Observable Adverse Effect Levels for chronic effects (reproduction effects over 3 generations). It is therefore unlikely that use of biosolids pellets around the home or in parks could pose a danger to pets.

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Introduction

The nutrient value and organic matter content of biosolids make them potentially useful as fertilizers and soil amendments. The spreading of biosolids on land has become a common biosolids management practice by municipalities in Ontario and across North America. Biosolids are products of the sewage treatment process, which consists of a combination of physical, chemical and biological processes. The solids remaining after the digestion process are dewatered to produce biosolids cake. Further heating and processing can be used to produce pellets. Biosolids cake or pellets may then be landfilled, incinerated or applied to land.

The Ashbridges Bay Treatment Plant (ABTP) is the largest of four wastewater treatment plants serving the City of Toronto. In 1998, the City of Toronto decided to pursue a policy of 100% beneficial use of biosolids at ABTP and installed a pelletizer. The pelletization plant was constructed at the ABTP in 2002 to convert 50% of the plant's biosolids into dry pellets, leaving 50% as dewatered cake. Both forms of biosolids could then be applied to land. The pelletizer that was installed was a Seghers HARDpelletizer, which produces pellets through an indirect heating process of coating a nucleus of dry biosolids with wet biosolids. The pellets are exposed to high temperatures and controlled dryer times. Pellets, approximately 3 mm in diameter, 97% solid (with the remaining 3% as water) and with greatly reduced pathogen content, can be achieved when the pelletizer is functioning optimally and meets all expected standards (Seghers Keppel, undated). Currently, the pelletizer is out of service following a fire in August 2003, but a portion of the dewatered cake continues to be land applied on agricultural lands while the majority is shipped to a landfill in Michigan. The City of Toronto produced 4,416 dry tonnes of pellets in 2002 and plans to repair the pelletizer plant.

Although biosolids are a potentially valuable resource, considerable public concern remains. Anecdotal evidence of illness associated with land application of biosolids cake is increasing (Lewis *et al.* 2000; Harrison, 2002), however, previous review of epidemiological evidence of health effects yielded mixed results (Apedaile *et al.* 2002). Most studies were either unable to demonstrate increased human health effects or found certain health effects to be somewhat increased but not significantly so. Some studies did find a significantly higher prevalence of gastrointestinal symptoms or headaches among sewage treatment plant workers (Khuder *et al.* 1998; Lundholm and Rylander, 1983) and slightly higher rates of viral infection among farm and resident populations (Caman *et al.* 1985; Northrop *et al.* 1980).

Little has been published about biosolids pellets making it difficult to determine the potential health effects of biosolids pellet use relying only on existing literature. Unlike biosolids cakes, pellets can potentially be used in an urban environment within the City of Toronto. Toronto Public Health therefore reviewed the data available to assess the degree to which exposure to pellets as a fertilizer or soil amendment could be of concern in Toronto.

This report examines the potential risks to people, plants and soil organisms, pets (cats and dogs), birds and other wildlife associated with the use of biosolids pellets in the City of Toronto. Potential exposure to metals and organic chemicals in pellets were quantitatively evaluated for three types of use contemplated for Toronto pellets:

- use of pellets on City-owned recreational areas such as parks and golf courses;
- home use of pellets on lawns and gardens by Toronto residents; and
- use of pellets as part of a landfill topdressing[1] mixture applied by the City of Toronto.

The assessment took into consideration the regulatory framework for land application of biosolids in Ontario. Risks associated with biological agents present in the pellets are discussed with respect to the effectiveness of the pelletization process to destroy these agents. Quantification of pathogenic risk as well as cumulative risk (resulting from interaction of all chemical and biological stressors) is not feasible because suitable analytical data are not available. Also, there are no well-defined guidelines for assessing risk from environmental exposure to biological agents and no clear definition for acceptability. The science of assessing pathogenic risk and cumulative risk is under development at the present time. Other emerging issues are also discussed in the report.

While Toronto pellets contain appreciable concentrations of many of the fifteen elements essential for plant growth (Brady, 2002), including nitrogen, phosphorus, boron, copper, cobalt, manganese, molybdenum, nickel and zinc, pellets do not contain much potassium. The pellets could potentially be used as soil amendments, as well as general-purpose lawn and garden fertilizers after being blended with a source of potassium and water-soluble nitrogen. More detailed information on the physical and chemical makeup of the pellets is required to establish the release rate of the humus (organic matter broken down to the point where it becomes very useful) and of the nutrients to determine their actual usefulness and suitability for different applications. This particular aspect is not addressed in this report.

[1] Landfill topdressing is a material applied as the final landfill cover, which is typically topsoil seeded to establish vegetative cover.

Regulatory Context

Land application of biosolids cake on agricultural land is regulated in Ontario through Regulation 347 of the Environmental Protection Act (1990), and Regulation 367/03 of the Nutrient Management Act (NMA, 2002). Municipal biosolids cakes are considered "non-agricultural source material" under the Nutrient Management Act and are subject to the Ontario Ministry of Environment's (MOE) *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land* (1996a). The Guidelines specify general rules for application of biosolids including separation distances from surface water, wells and residences, application rates and quality standards for eleven inorganic elements. In addition, a Certificate of Approval containing site-specific terms and conditions for land application must be obtained for each application site. Soil testing is often required. Regulation 267/03 prohibits the application of a non-agricultural source material to "the land of an established golf course or to land on which tobacco grow".

Regulations in Canada and the United States permit the use of biosolids products (i.e. saleable items) outside of agriculture. Biosolids products sold as fertilizers or soil supplements are regulated by the Federal Fertilizers Act (1985), which specifies standards for labelling, registration and product quality including the level of metals in the product. The Act has no monitoring requirement regarding product use. The Fertilizers Act is administered by the Canadian Food Inspection Agency (CFIA). The City of Toronto has voluntarily applied to the CFIA for a "letter of no objection". The CFIA did not, however, undertake a safety study of the pellets. The label for the pellets is illustrated in Figure I.

The Certificate of Approval issued for the ABTP pelletizer indicates that if the pellets meet the standards of the Fertilizers Act (CFIA, 1997) and they are offered for sale, they are no longer considered a waste; rather they are considered a product. But because pellets produced by the City contain 10% or less of total nitrogen, available phosphorus and soluble potash, the pellets will be considered as "non-agricultural source material" under the Nutrient Management Act and regulations even if they are sold. Like pellets that are not sold but given away, Toronto pellets are regulated by the same Provincial regulations as biosolids cake when applied on agricultural land. The Ontario regulatory framework provides for non-agricultural uses of biosolids, although the regulatory processes governing some of these uses, such as reclamation of mine tailing, have not been worked out (Schut, 2004).

Figure I City of Toronto Label for ABTP Produced Biosolids Pellets

11/12/01

NUTRI-PEL

Processed Sewage 3.5 – 5.0 – 0.0

Guaranteed Minimum Analysis

Total Nitrogen	(N)		-	3.5 %
3.25% Water insoluble Nitrogen (N)				
Available Phosphoric Acid	(P_2O_5)		-	5.0 %
Iron	(Fe)	Actual	-	5.0 %
Organic Matter			-	50 %
Maximum Moisture			-	10 %

Directions for Use:

This product is derived from digested municipal sewage that has been dried and pelletized at high heat.

The recommended rate of application for this product is dependent upon the crop it is applied to. This product should be used in accordance with all applicable fertilizer recommendations published by the Ontario Ministry of Agriculture Food Approximately 20% of the Total nitrogen is available in the 1st year of application.

Caution:

This fertilizer contains copper and should be used only as recommended. It may prove harmful when misused.
Do not exceed crop specific nutrient application rates as recommended in published OMAF fertilizer recommendations.
Do not exceed an application rate of 2.7 tonnes of product per Hectare per year.

Product Storage:

Store product in a dry location until application.

Weight:

Weight on Bill of Lading (attached)

Responsible Packager's Name and Address:

USF Canada Inc.
250 Royal Crest Court
Markham, Ontario, CANADA L3R3S1
Telephone: 800-663-2463

Levels of Chemicals in Biosolids

Works and Emergency Services of the City of Toronto collects and analyzes samples of biosolids cake from the ABTP for eleven regulated inorganic elements, nutrients and total solids every two weeks. As required by the MOE (1996a), the contents of the metals for the cake are determined from a liquid biosolids sample and reported on a dry weight basis. Pellets are also analyzed for a similar set of parameters as biosolids cake. Data on the eleven regulated elements in ABTP biosolids cake for the past 14 years were available from April 1989 to the end of 2003. There were also data for cadmium, chromium, copper, nickel, lead and zinc starting in 1978. Pellet data were more limited and were available only for the time period September 2002 to the end of 2003. In addition to the biweekly monitoring, the City of Toronto performs annual plant performance evaluations and includes hourly sampling over a 22-hour period. During this sampling period, an extensive list of parameters is tested including polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (dioxins) and polychlorinated dibenzofurans (furans).

Quantitative exposure assessment was conducted only for entities of potential concern for which the City has adequate information on their levels in the biosolids. Table I presents the chemical entities of potential concern for which Works and Emergency Services has analytical data and hence were included in the analysis. The inorganic elements were selected based on current standards and regulations regarding biosolids, their contribution to plant growth and data quality. Among the eleven inorganic elements that were selected, five (copper, cobalt, molybdenum, nickel and zinc) are considered essential micronutrients for plant growth.

Chromium is a naturally occurring element most commonly found in the form of chromium III and VI. The Council for Agricultural Science and Technology in the USA (WEAO, 2001) found that chromium VI does not occur in many biosolids because it is reduced to the less toxic chromium III state during biosolids digestion. Even if chromium VI is present, because of its higher solubility and lower tendency to adsorb to particulate matter, it is not expected to precipitate out of wastewater to the same extent as chromium III. In the long-term, pellets would be integrated into the soil phase. Chromium III can persist and accumulate in soils because of its association with relatively inert phases. Although very little literature exists on the species of chromium present in soils, nearly all the chromium in soils (excluding those recently contaminated with chromium VI) is likely present as chromium III (Environment Canada and Health Canada, 1994; ATSDR, 2000; WEAO, 2001). Chromium VI may be present in the soil for a short time but is reduced to chromium III and then to lower solubility compounds (WEAO, 2001). The City of Toronto measured total chromium. Since the specific species of chromium were not measured, chromium III was evaluated as representative of total chromium.

Table I: Selected Chemicals (Entities of Potential Concern) for Quantitative Evaluation

Inorganics		Trace Organics
Arsenic[a] (As) Cadmium[b] (Cd) Cobalt (Co) Chromium III[c] (Cr III) Copper (Cu) Mercury (Hg)	Molybdenum (Mo) Nickel[b] (Ni) Lead (Pb) Selenium (Se) Zinc (Zn)	PCBs[a] Dioxins[a] (PCDDs) Furans[a] (PCDFs)

Notes:

a. Substances evaluated as cancer-causing when ingested and inhaled.
b. Substances evaluated as cancer causing when inhaled.
c. Since the specific species of chromium were not measured, chromium III was evaluated as representative of total chromium instead of chromium VI.

There were only limited analytical data for trace organics in ABTP biosolids. The scarcity of data would introduce a high degree of uncertainty into any risk assessment of these substances. Nonetheless, PCBs, dioxins and furans were included in the analysis because of public concerns regarding the potential adverse health effects associated with these trace organic compounds. Even though the data for Toronto biosolids are limited (one observation for PCBs and five for dioxins and furans), the larger base of information on these chemicals in biosolids (MOE, 1988; Webber and Nichols, 1995; Webber and Lesage, 1988), makes the evaluation of these chemicals more practical.

The levels of metals in Toronto biosolids vary over time, generally showing a downward trend from the late seventies to 2003 (data not shown). A change in industrial activities and practices in the City over the years is a major factor for the observed change in metal levels. Given improvement over treatment efficiency, changes in the types of industrial operations in Toronto, greater control over discharges to the sewer, and the start of the pilot program to apply biosolids on land since 1995, cake data from 1996 to 2003 were deemed to be the most representative of current biosolids quality. Another important event that impacts on the levels of contaminants in the biosolids is the enactment of the revised Toronto Sewer Use By-law in July 2000. The revised By-law contains more stringent discharge limits for contaminants and requires industries to submit pollution prevention plans starting on June 30, 2001. Comparison of biosolids metal contents for the period of 1996-2000 to the period of 2001-2003 (Table II) shows a statistically significant decrease for arsenic, chromium, nickel, lead and zinc. For mercury (Figure IIa), there is a decrease in concentration from 1996-2000 to 2001-2003, but the decrease is not statistically significant. However, there appears to be a big drop from 2001 to 2002-2003, corresponding to the enforcement of the revised Sewer Use By-law, which began in June 2001. While there is generally not much change in the levels for cadmium, copper, molybdenum and selenium, the concentration of cobalt increases between the periods 1996-2000 and 2001-2003 (Figure IIb).

Table II: Comparison of Metal Concentrations in Biosolids Cake (on a Dry Weight Basis) for the Time Periods 1996-2000 and 2001-2003

Metal	Concentration (mg/kg)				
	1996-2000		2001-2003		Trend
	Mean ± S.D.	N	Mean ± S.D.	N	
Arsenic	8.79 ± 6.23	107	4.83 ± 4.20[a]	66	Decrease
Cadmium	4.86 ± 4.00	108	4.15 ± 2.53	66	No significant change
Cobalt	1.70 ± 2.16	108	4.98 ± 0.80[a]	66	Increase
Chromium	170.4 ± 52.0	108	121.2 ± 30.0[a]	66	Decrease
Copper	1137.0 ± 124.6	108	1144.0 ± 114.3	66	No significant change
Mercury	1.64 ± 0.74	102	1.53 ± 0.88	66	No significant change
Molybdenum	11.51 ± 6.18	108	12.43 ± 4.21	66	No significant change
Nickel	40.14 ± 12.41	107	30.56 ± 14.30[a]	66	Decrease
Lead	100.2 ± 37.8	108	67.76 ± 8.99[a]	66	Decrease
Selenium	2.82 ± 1.28	108	3.13 ± 1.23	66	No significant change
Zinc	914.4 ± 131.9	108	812.1 ± 108.7[a]	66	Decrease

Notes:

a. Significantly different from the 1996-2000 mean concentration, $p < 0.001$.
Statistical analyses done by 2-tailed Student t-test for equality of means.

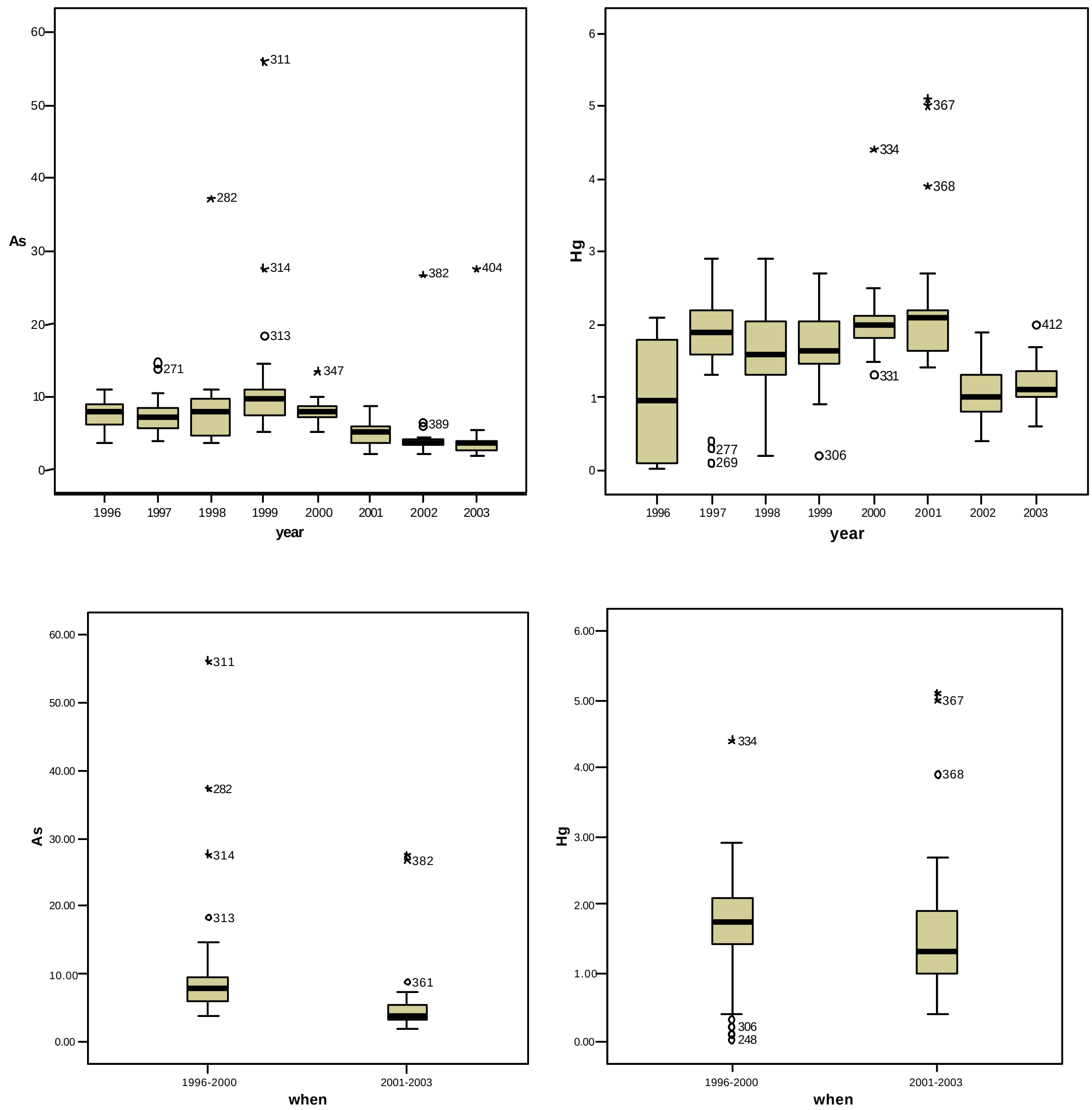


Figure IIa Concentration-Time Trend for Arsenic (As) and Mercury (Hg) in Biosolids Cake from 1996 to 2003; Comparison of Metal Concentrations between the Time Periods 1996-2000 and 2001- 2003. Data points outside the box and whisker plots are outliers to where most of the numbers are. The box stretches between the 75th and 25th percentiles[2]. The bold line inside the box is the median (50th percentile). The whiskers stretch between the smallest and largest values in the main cluster of numbers.

[2] 75 percent of the numbers are below the 75th percentile value, half the numbers are below the median and 25 percent of the numbers are below the 25th percentile value.

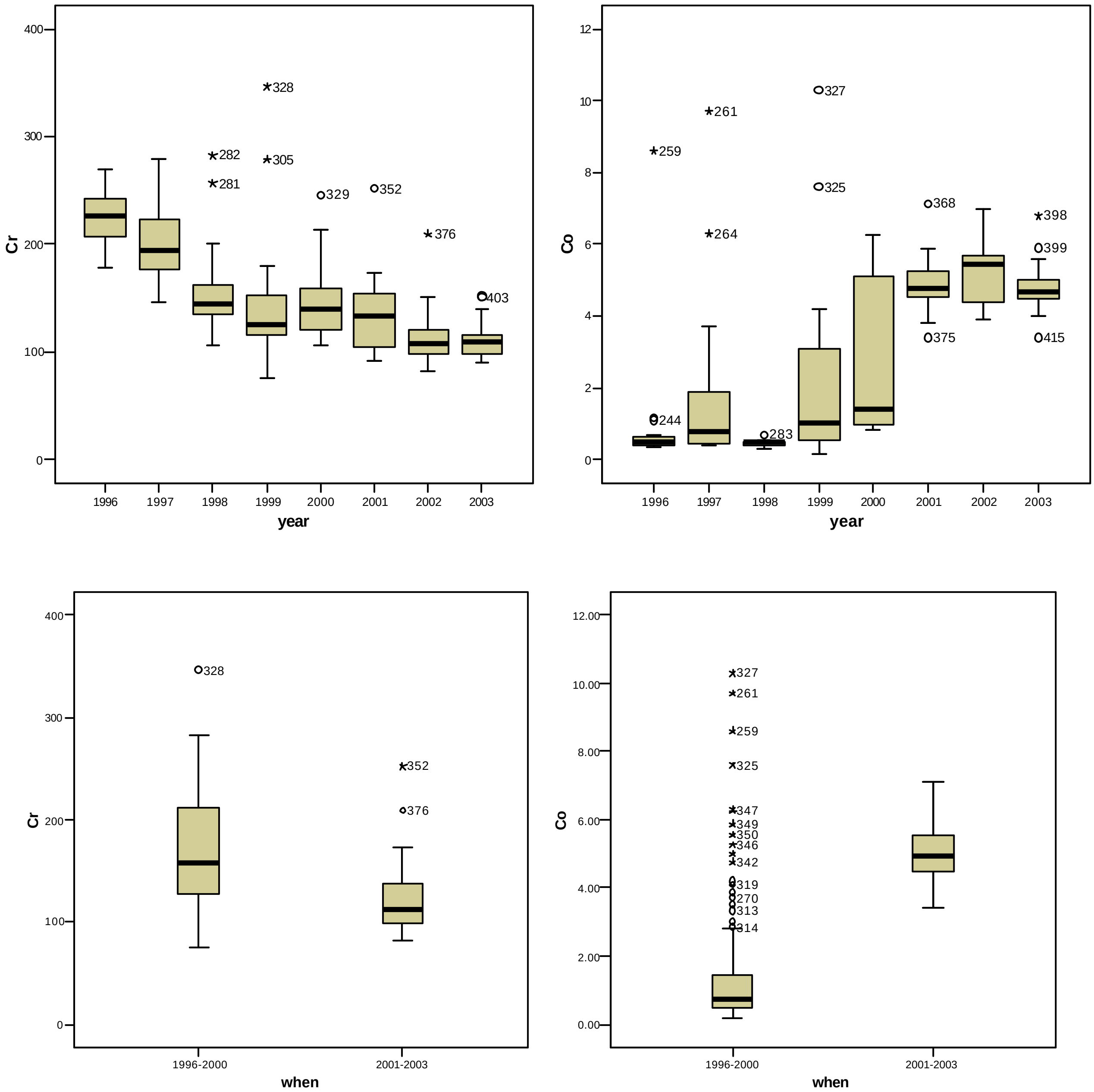


Figure IIb Concentration-Time Trend for Chromium (Cr) and Cobalt (Co) in Biosolids Cake from 1996 to 2003; Comparison of Metal Concentrations between the Time Periods 1996-2000 and 2001-2003. Data points outside the box and whisker plots are outliers to where most of the numbers are. The box stretches between the 75th and 25th percentiles. The bold line inside the box is the median (50th percentile). The whiskers stretch between the smallest and largest values in the main cluster of numbers.

Levels of Chemicals in Pellet-Amended Soil

The biosolids analytical data were used to estimate the potential future concentrations of chemicals in the soil as a result of biosolids pellet application for each chemical entity of potential concern. Because the cake data set was more complete than the pellet data set, it was used to determine input values for the risk assessment. Use of cake data tends to overestimate rather than underestimate chemical concentrations in pellets, especially for the more volatile chemicals. This is because the concentrations of the chemicals in the cake are determined from a liquid biosolids sample on a dry weight basis[3]. For volatile chemicals with low vapour pressure, such as arsenic and mercury, there will also be some evaporation in the pelletizer. Although there was some variance between the cake and pellet data sets in metal concentrations, it was not believed to have a significant impact in the conduct of human and ecological risk assessment.

To estimate the levels of chemicals in pellet-amended soils, the pellets were assumed to be incorporated into garden soils to a depth of 15 cm and restricted to the top 5 cm when applied on sod (lawns). The pellets were assumed to be mixed into topdressing applied over final landfill cover to facilitate seeding.

The expected lifetime of the pelletizer is 25 years, therefore it was assumed that pellets were applied for twenty-five years. To take into consideration that because of their limited value as a fertilizer, some people might use more than the maximum recommended amount of pellets (2.7 tonnes per hectare per year), twice the maximum recommended application rate (5.4 tonnes per hectare per year) was assumed. These assumptions regarding use likely overestimate the risk for a twenty-five year period. Also other removal mechanisms including leaching from soils, removal via uptake by plants, removal in surface runoff from rain or other precipitation, or other removal mechanisms that will occur over this period of time are not considered in the evaluation.

[3] The Ontario Ministry of the Environment requires the chemical content of biosolids to be measured from liquid samples and reported on a dry-weight basis. This measures the total amount of a substance in both the liquid and solid portion of biosolids and reports it as the amount of a completely dried product. When biosolids are dewatered to make cake, part of the liquid, which contains some dissolved chemicals, is removed. This means that the portion that is left behind (the cake) will contain a lower concentration of the substance than in the original liquid biosolids. If the liquid content is then further removed through some process like low temperature evaporation, the chemical content measured on a dry-weight basis generally would not change.

The levels of metals in the pellets were assumed not to be just the average of the biosolids samples collected from 1996 to 2003, but the 95% upper confidence limit of the mean[4] - which is considered an upper estimate of the average pellet concentration and will tend to overestimate concentrations over time. For dioxins and furans, the average value was used in the assessment as there were only five observations. The values used for PCBs, dioxins and furans are close to the upper end of the concentration range found in Ontario biosolids (WEAO, 2002) and are appropriate for a "worst case' standpoint. The resulting chemical levels calculated for pellet-amended soil, for dust and vapour arising from this soil, and for garden produce grown on this soil are considered to provide an upper estimate of concentrations for the evaluation of long term pellet application. These values are presented in Table III

[4] The mean concentration is equal to or below this value 95% of the time.

Table III: Upper Estimates of Chemical Levels in Pellet-Amended Soil, Dust and Vapour, and Garden Produce

EoPC	Pellets[c] (mg/kg)	Amended Soil[a] (mg/kg)		Landfill Top[a] Dressing (mg/kg)	Garden Produce[a] (mg/kg, wet weight)			Dust In Air[a] (mg/m^3)		Vapours[a] (mg/m^3)
		5 cm Depth	15 cm Depth		Fruit	Vegetables		From 5 cm Soil	From 15 cm Soil	From 5 cm Soil
						Root	Above Ground			
Inorganics										
As	8.1	4.1	3.0	0.32	0.0034	0.0034	0.033	3.1×10^{-7}	2.2×10^{-7}	NA [b]
Cd	5.1	1.3	0.65	0.20	0.018	0.018	0.092	1.0×10^{-7}	4.9×10^{-8}	NA [b]
Co	3.3	8.4	7.9	0.13	0.011	0.011	0.030	6.4×10^{-7}	6.0×10^{-7}	NA [b]
Cr	160	58	37	6.2	0.031	0.031	0.052	4.4×10^{-6}	2.8×10^{-6}	NA [b]
Cu	1200	260	110	45	5.1	5.1	2.3	2.0×10^{-5}	8.2×10^{-6}	NA [b]
Hg	1.7	1.1	0.92	0.067	0.035	0.035	0.066	8.7×10^{-8}	7.0×10^{-8}	NA [b]
Mo	13	2.8	1.1	0.50	0.013	0.013	0.053	2.1×10^{-7}	8.4×10^{-8}	NA [b]
Ni	39	23	18	1.5	0.20	0.20	0.18	1.7×10^{-6}	1.3×10^{-6}	NA [b]
Pb	93	54	41	3.6	0.071	0.071	0.40	4.1×10^{-6}	3.1×10^{-6}	NA [b]
Se	3.1	1.1	0.69	0.12	0.0033	0.0033	0.064	8.5×10^{-8}	5.3×10^{-8}	NA [b]
Zn	900	260	140	35	23	23	14	2.0×10^{-5}	1.0×10^{-5}	NA [a]
Trace Organics										
PCBs[d]	1.7×10^{-4}	0.011	0.011	6.5×10^{-6}	2.0×10^{-5}	2.0×10^{-5}	2.0×10^{-5}	8.0×10^{-10}	8.0×10^{-10}	1.3×10^{-9}
PCDD/Fs[d,e]	1.5×10^{-5}	4.7×10^{-6}	2.7×10^{-6}	5.8×10^{-7}	2.9×10^{-9}	2.9×10^{-9}	2.9×10^{-9}	3.6×10^{-13}	2.1×10^{-13}	8.5×10^{-14}

Note:

a. Chemical levels after 25 years of annual pellet application at double the maximum recommended application rate (i.e. 5.4 tonnes per hectare per year).

b. Inorganic compounds generally do not volatilize and therefore have not been considered for vapour inhalation.

c. The upper estimates of pellet metal concentrations are based on the 95th upper confidence limit of the mean measured concentrations in biosolids cake.

d. Given that the available data are limited, the mean concentrations for trace organics were used in the assessment.

e. Total dioxins and furans.

Human Health Risk from Chemical Exposure

Risk is composed of two elements – the level of exposure to a substance and the degree of hazard the substance poses. The risk to people from exposure to chemicals present in pellets was assessed for the most sensitive or representative receptors under each of the three types of use contemplated for Toronto pellets. Table IV summarizes these receptors, which include the following exposure scenarios:

- City Parks Workers applying pellets on City-owned recreational areas such as parks and golf courses;
- City Landfill Workers applying topdressing to landfills, over the final cover to facilitate seeding;
- Recreational Users using City parks or golf courses where pellets were used;
- Home Users using pellets on their lawns or gardens, and eating fruits and vegetables from their gardens.

Among the residents, children between the ages of 7 months and 5 years are commonly selected as the most sensitive receptors with the greatest exposure due to their low body weight, higher metabolic rate and hand-to-mouth activity. Pica behaviour (the repeated eating of non-nutritive substance) among children between the ages of 1 and 3 years has not been considered in the assessment. Children with soil pica behaviour (earth eating) can ingest as much as 10 g of soil a day (NRC, 2002) and would be at much higher risk than children without the behaviour. However, the incidence rate of deliberate soil ingestion behaviour in the general population is thought to be low (USEPA, 1997a).

Cancer risk is evaluated for exposure over a lifetime. The Recreational Use Scenario assumes that the composite[5] receptor attends City owned recreational areas treated with pellets throughout their lifetime (75 years). Under the Home Use Scenario, the composite receptor was assumed to live all his life in a household that uses pellets on lawns and gardens. Differences in lifestyle and biological factors at different stages of life were incorporated in the assessment of lifetime exposures.

[5] To take into account the variation in exposures during different life stages (such as toddler, child, youth and adult), lifetime exposures were calculated by combining the exposures from each lifestage and averaging over a 75-year period, resulting in a composite (or lifetime) receptor.

Table IV: Selected Receptors

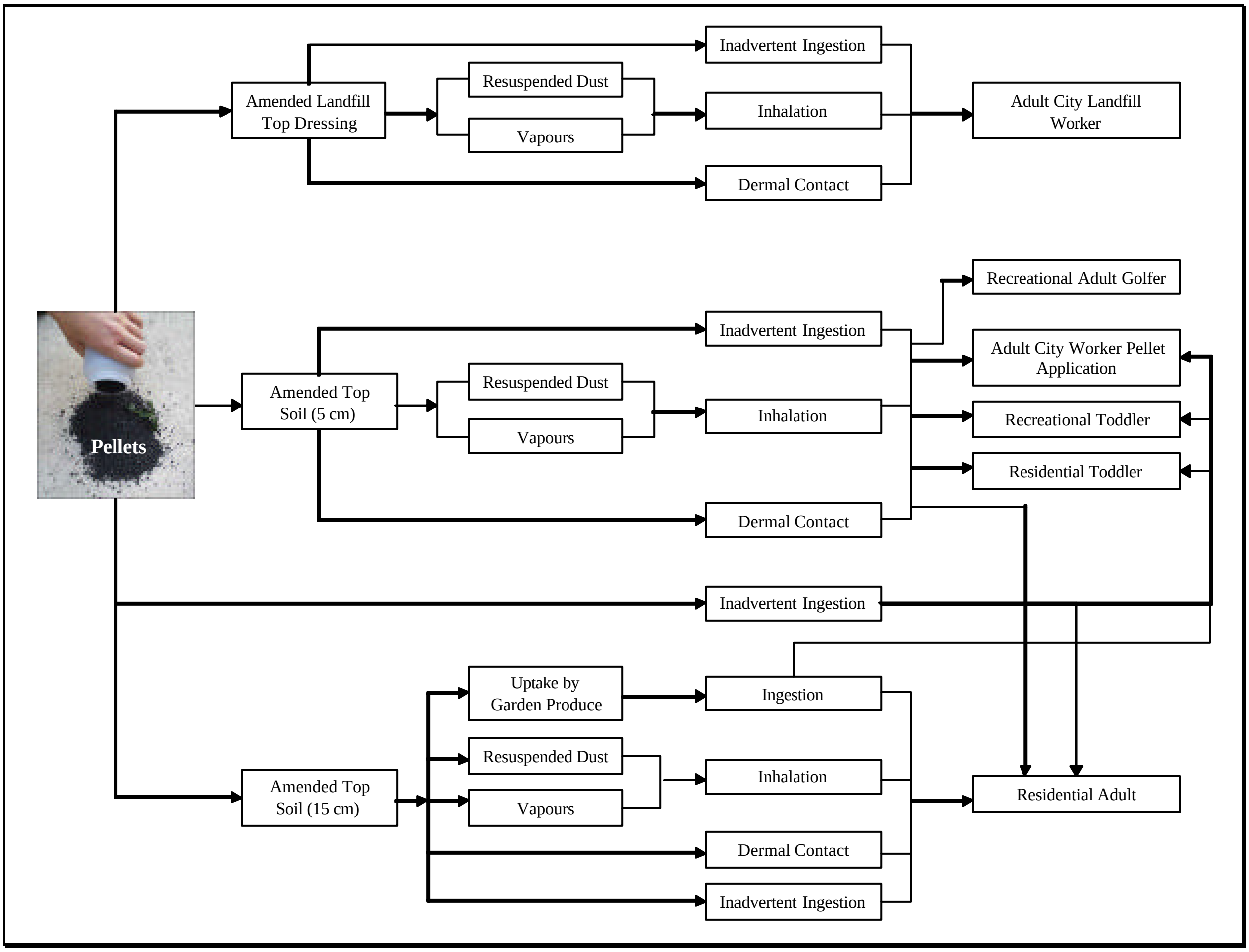
Scenario	Health Effect	
	Non-Carcinogen	Carcinogen
City Workers	Adult City Parks Worker exposed to pellets for 30 years in City-owned recreational areas (parks, golf courses, and gardens)	Adult City Parks Worker exposed to pellets in City-owned recreational areas (parks, golf courses, and gardens) for 30 years
	Adult City Landfill Worker exposed to amended landfill top dressing for 30 years	Adult City Landfill Worker exposed to amended landfill top dressing for 30 years
Recreational Use (parks, golf courses)	Toddler exposed to pellets and amended soil for 4.5 years (between the ages of 7 months to 5 years)	Composite receptor that represents a lifetime of visiting the park for 75 years (from birth to 75 years old)
	Adult golfer exposed to amended soil for 30 years	Adult golfer exposed to amended soil for 30 years
Home use (garden, lawn)	Toddler exposed to pellets, amended soil and impacted garden produce for 4.5 years (between the ages of 7 months to 5 years)	A composite receptor that represents a lifetime of exposure for 75 years (from birth to 75 years old)
	Adult resident exposed to pellets, amended soil, impacted garden produce and exposure while applying pellets for 55 years (from 20 to 75 years of age)	

The receptors are exposed to pellets directly or to amended soil under various situations. For some chemicals (such as arsenic, lead and cobalt), the bioavailability from soil is higher in acidic soils. However, soils in Southern Ontario are generally not acidic (MOE, 1993; Hoffman *et al.* 1964; Chapman and Putnam, 1984). The exposure pathways are presented in Figure III. In general, ingestion of pellets, pellet-amended soils, inhalation of dust and vapour, and dermal contact were considered in exposure estimation for pellet use on parkland and lawns (pellet incorporated in soil to a depth of 5 cm)[6]. Ingestion of vegetables and fruits grown on pellet-amended soil is an additional exposure pathway that was considered for pellet use in home garden (pellet incorporated in soil to a depth of 15 cm)[6]. Once applied on lawns, the pellets will migrate down through the grass foliage to the surface of the soil or thatch layer, and will not be readily available for children to pick up and ingest. Since it could take days before pellets get incorporated into the soil under arid conditions, the calculation took into account the scenario that children under 5 years old ingest pellets they might pick up on

[6] A surface soil mixing depth of 5 cm and garden soil depth of 15 cm were selected to be consistent with the derivation of the Ontario Typical Range (OTR_{50}, median background levels) developed by the Ontario Ministry of the Environment. Soil samples were collected throughout Ontario at 0 to 5 cm depth for all areas except gardens or tillage, where 0 to 15 cm depth was considered (MOE, 1993).

patches of bare soil surface[7]. However, the pellets are very small and have similar colour as the soil. Therefore, they are less likely to be noticed or ingested than fertilizer pellets.

Figure III: Exposure Pathways and Receptors



In general, where there were information gaps, assumptions that likely result in overestimation of the risk were made in order to assure that risks were not underestimated. The goal is to achieve a reasonable upper estimate of the risk for the most sensitive or representative receptor under the various exposure scenarios. Details on the derivation of the risk estimates are available in the report *Biosolids Pellet Review Study: Human Health and Ecological Risk Assessment* prepared for Toronto Public Health by Jacques Whitford Environment Limited.

[7] Area of soil not covered by sod or grass or other vegetation.

Risk from a given substance is related to the degree of hazard the substance poses (i.e. potency). The potencies for inhalation and oral routes of exposure were adopted from published values by regulatory agencies such as Health Canada, United States Environmental Protection Agency (USEPA) and the Ontario Ministry of the Environment (MOE) after a review of their scientific basis. Potencies for dermal exposure were available for very few chemical substances. The common practice is to evaluate dermal exposure using oral potencies after correcting for differences in absorption for the two different routes of exposure (USEPA, 1989, 1992). This practice implicitly assumes that health effects are related only to the total uptake of the chemical into the body and not dependent on the route of exposure.

Additive effects are applicable when two or more chemicals affect the same target organ and induce a common toxic effect. The individual, independent risks are "added" together and ultimately increase the aggregate risk to the receptor. Health risks from PCBs, dioxins and furans have been quantitatively evaluated as whole mixtures. For the other chemicals evaluated in the risk assessment, the health benchmarks are generally based on different toxicological mechanisms and/or endpoints and therefore assessing additive effects is not considered applicable for these chemicals.

One way to estimate if exposure levels are of concern is to calculate the hazard quotient (for non-cancer effects) or the exposure ratio (for cancer effects). The ratios compare estimated exposure levels against the health benchmarks[8]. According to MOE guidance (MOE, 1996b), since background exposure including exposure from supermarket foods has not been addressed, a hazard quotient less than 0.2 (i.e. 20% of total allowable exposure) for each exposure pathway is considered protective of health. The hazard quotients for the inhalation pathway and the combined oral and dermal exposure pathways from exposure after 25 years of pellet application were below 0.2 for all the chemicals evaluated under all exposure scenarios considered (Table V). The hazard quotients would also be below 0.2 for City Parks workers who also use pellets at home, residents who use pellets at home and go to recreational spaces which use pellets.

For cancer effects, cancer risks were compared to the Health Canada benchmark of negligible risk (risk of one in a hundred thousand; Health Canada, 2003) as well as the MOE benchmark (risk of one in a million; MOE, 1996b). Exposure ratios greater than one suggest that exposures are above the benchmark but do not necessarily imply an elevated level of risk because of the uncertainties inherent in the risk assessment. With the exception of arsenic, the

[8] For non-cancer effects, health benchmarks are exposure levels below which health effects are not expected.

exposure ratios for all chemicals were below one for all scenarios considered using either the Health Canada or MOE benchmarks (Table VI and VII). The exposure ratios for these chemicals would also be equal to or below one for City Parks workers who also use pellets at home, residents who use pellets at home and go to recreational spaces, which use pellets.

Table V Estimated Risk of Non-Cancer Effects to Selected Receptors from Exposure to Chemicals in Pellets under Various Pellet Use Scenarios

	Hazard Quotient[d]											
EoPC	City Parks Worker		City Landfill Worker		Toddler - Park Use		Toddler - Home Use		Adult - Park Use		Adult - Home Use	
	Total Ingestion/ Dermal	Inhalation[a]	Total Ingestion/ Dermal	Inhalation[a]	Total Ingestion/ Dermal	Inhalation[a]	Total Ingestion/ Dermal	Inhalation[a]	Total Ingestion/ Dermal	Inhalation[a]	Total Ingestion/ Dermal	Inhalation[a]
As	5×10^{-3}	NA[b]	2×10^{-4}	NA[b]	3×10^{-2}	NA[b]	3×10^{-2}	NA[b]	8×10^{-4}	NA[b]	8×10^{-3}	NA[b]
Cd	7×10^{-3}	NA[b]	3×10^{-4}	NA[b]	1×10^{-2}	NA[b]	7×10^{-2}	NA[b]	7×10^{-4}	NA[b]	2×10^{-2}	NA[b]
Co	4×10^{-6}	2×10^{-3}	3×10^{-7}	1×10^{-4}	2×10^{-5}	2×10^{-3}	6×10^{-4}	2×10^{-3}	3×10^{-5}	5×10^{-3}	2×10^{-4}	3×10^{-3}
Cr	8×10^{-5}	NA[c]	3×10^{-6}	NA[c]	2×10^{-4}	NA[c]	2×10^{-4}	NA[c]	7×10^{-6}	NA[c]	1×10^{-5}	NA[c]
Cu	3×10^{-2}	NA[c]	1×10^{-3}	NA[c]	2×10^{-2}	NA[c]	6×10^{-2}	NA[c]	2×10^{-3}	NA[c]	4×10^{-2}	NA[c]
Hg	4×10^{-3}	7×10^{-5}	2×10^{-4}	6×10^{-6}	1×10^{-2}	2×10^{-5}	1×10^{-1}	2×10^{-5}	7×10^{-4}	5×10^{-5}	4×10^{-2}	3×10^{-5}
Mo	2×10^{-3}	NA[c]	7×10^{-5}	NA[c]	3×10^{-3}	NA[c]	7×10^{-3}	NA[c]	1×10^{-4}	NA[c]	1×10^{-3}	NA[c]
Ni	2×10^{-3}	NA[b]	7×10^{-5}	NA[b]	5×10^{-3}	NA[b]	1×10^{-2}	NA[b]	5×10^{-4}	NA[b]	3×10^{-3}	NA[b]
Pb	1×10^{-2}	NA[c]	4×10^{-4}	NA[c]	3×10^{-2}	NA[c]	7×10^{-2}	NA[c]	1×10^{-3}	NA[c]	1×10^{-2}	NA[c]
Se	4×10^{-4}	NA[c]	2×10^{-5}	NA[c]	1×10^{-3}	NA[c]	4×10^{-3}	NA[c]	4×10^{-5}	NA[c]	1×10^{-3}	NA[c]
Zn	2×10^{-3}	NA[c]	8×10^{-5}	NA[c]	4×10^{-3}	NA[c]	7×10^{-2}	NA[c]	2×10^{-4}	NA[c]	2×10^{-2}	NA[c]
PCBs	6×10^{-6}	NA[c]	2×10^{-7}	NA[c]	1×10^{-3}	NA[c]	2×10^{-3}	NA[c]	1×10^{-4}	NA[c]	4×10^{-4}	NA[c]
PCDD/Fs[e]	5×10^{-3}	NA[c]	2×10^{-4}	NA[c]	1×10^{-2}	NA[c]	1×10^{-2}	NA[c]	5×10^{-4}	NA[c]	8×10^{-4}	NA[c]

Note:

a. Concentration in air evaluated as airborne particulate from amended soil at 5 cm depth.
b. Not Applicable: EoPC evaluated as a carcinogen following inhalation.
c. Not Applicable: Inhalation hazard quotient not evaluated because there are no applicable inhalation health benchmark for the corresponding EoPC.
d. Hazard quotient = estimated exposure level/health benchmark.
e. Total dioxins and furans.

Table VI Estimated Cancer Risk to Selected Receptors from Ingestion and Dermal Exposure to Chemicals in Pellets under Various Exposure Scenarios

	Exposure Ratio[a] (ER)									
EoPC	City Parks Worker		City Landfill Worker		Composite (Lifetime) Park Use		Composite (Lifetime) Home Use		Adult - Park Use	
	Total Ingestion/Dermal		Total Ingestion/Dermal		Total Ingestion/Dermal		Total Ingestion/Dermal		Total Ingestion/Dermal Cancer Risk ER	
	1×10^{-5} [b]	1×10^{-6} [c]	1×10^{-5} [b]	1×10^{-6} [c]	1×10^{-5} [b]	1×10^{-6} [c]	1×10^{-5} [b]	1×10^{-6} [c]	1×10^{-5} [b]	1×10^{-6} [c]
As	9×10^{-2}	9×10^{-1}	3×10^{-3}	3×10^{-2}	7×10^{-2}	7×10^{-1}	5×10^{-1}	5	3×10^{-2}	3×10^{-1}
Cd	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]
Co	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]
Cr	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]
Cu	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]
Hg	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]
Mo	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]
Ni	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]
Pb	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]
Se	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]
Zn	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]
PCBs	9×10^{-6}	9×10^{-5}	4×10^{-7}	4×10^{-6}	8×10^{-4}	8×10^{-3}	2×10^{-3}	2×10^{-2}	3×10^{-4}	3×10^{-3}
PCDD/Fs[e]	6×10^{-2}	6×10^{-1}	3×10^{-3}	3×10^{-2}	3×10^{-2}	3×10^{-1}	5×10^{-2}	5×10^{-1}	1×10^{-2}	1×10^{-1}

Note:

a. Exposure Ratio = estimated exposure level/health benchmark.

b. Health Canada's benchmark for negligible cancer risk of one in a hundred thousand (Health Canada, 2003).

c. Ontario Ministry of the Environment's benchmark for negligible cancer risk of one in a million (MOE, 1996b).

d. Not Applicable: Not evaluated as a carcinogen for this route of exposure.

e. Total dioxins and furans.

Table VII Estimated Cancer Risk to Selected Receptors from Inhalation Exposure to Chemicals in Pellets under Various Exposure Scenarios

EoPC	Exposure Ratio[a] (ER)									
	City Parks Woke		City Landfill Worker		Composite (Lifetime) Park Use		Composite (Lifetime) Home Use		Adult - Park Use	
	Inhalation[b]		Inhalation[b]		Inhalation[b]		Inhalation[b]		Inhalation[b]	
	1×10^{-5} [c]	1×10^{-6} [d]	1×10^{-5} [c]	1×10^{-6} [d]	1×10^{-5} [c]	1×10^{-6} [d]	1×10^{-5} [c]	1×10^{-6} [d]	1×10^{-5} [c]	1×10^{-6} [d]
As	4×10^{-2}	4×10^{-1}	3×10^{-3}	3×10^{-2}	8×10^{-3}	8×10^{-2}	1×10^{-2}	1×10^{-1}	2×10^{-2}	2×10^{-1}
Cd	6×10^{-2}	6×10^{-1}	5×10^{-3}	5×10^{-2}	6×10^{-3}	6×10^{-2}	8×10^{-3}	8×10^{-2}	2×10^{-2}	2×10^{-1}
Co	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]
Cr	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]
Cu	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]
Hg	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]
Mo	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]
Ni	1×10^{-2}	1×10^{-1}	9×10^{-4}	9×10^{-3}	3×10^{-3}	3×10^{-2}	4×10^{-3}	4×10^{-2}	7×10^{-3}	7×10^{-2}
Pb	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]
Se	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]
Zn	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]
PCBs	1×10^{-5}	1×10^{-4}	1×10^{-5}	1×10^{-4}	1×10^{-5}	1×10^{-4}	1×10^{-5}	1×10^{-4}	1×10^{-5}	1×10^{-4}
PCDD/Fs[f]	9×10^{-4}	9×10^{-3}	3×10^{-4}	3×10^{-3}	4×10^{-4}	4×10^{-3}	4×10^{-4}	4×10^{-3}	5×10^{-4}	5×10^{-3}

Note:

a. Exposure Ratio = estimated exposure level/health benchmark.
b. Concentration in air evaluated as airborne particulate from amended soil at 5 cm depth.
c. Health Canada’s benchmark for negligible cancer risk of one in a hundred thousand (Health Canada, 2003).
d. Ontario Ministry of the Environment’s benchmark for negligible cancer risk of one in a million (MOE, 1996b).
e. Not Applicable: Not evaluated as a carcinogen for this route of exposure.
f. Total dioxins and furans.

In the case of arsenic, the cancer risk for the composite (lifetime) receptor resulting from ingestion/dermal exposure after 25 years of pellet use in the home environment was estimated to be five in a million. The estimated cancer risk is lower than the Health Canada benchmark of one in a hundred thousand. Ingestion of fruits and vegetables grown in pellet-amended soil constitutes 79% to the total cancer risk (Figure IV). This suggests that cancer risk as a result of using pellets on lawn alone would also meet the MOE benchmark of one in a million. The lifetime cancer risk for City Parks workers who also use pellets at home is estimated to be less than 6 in a million (mainly from eating vegetables and fruits from the home garden). The cancer risk for residents who use pellets at home and go to recreational spaces, which use pellets, would remain around five in a million.

The cancer risk for arsenic was overestimated using the biosolids cake data (mean concentration = 7.3 mg/kg) which was found to be substantially higher than pellets (mean concentration = 2.6 mg/kg). As shown in Table II and Figure IIa, in recent years, the arsenic levels in the biosolids are decreasing over time. The drop in concentration is statistically significant between the periods 1996-2000 and 2001-2003, corresponding to the enactment of the Toronto revised Sewer Use By-law in July 2000. If the trend continues, the actual arsenic concentration in the pellet-amended soil after 25 years of pellet application will likely be lower than the value used for the assessment. Many fertilizers contain traces of arsenic (WSDA, 2004); the levels of arsenic in the biosolids pellets are below allowable limits for fertilizers. In addition, the arsenic concentration in pellets is similar to the arsenic background soil concentration in Toronto (2.4 mg/kg).

Cobalt is the only metal that shows an increase (by about 3-fold) in its content in biosolids between 1996-2000 and 2001-2003. However, the estimated exposure levels of cobalt from inhalation and ingestion/dermal exposures after 25 years of pellet application were at least 1000 (ranged from a thousand to a million) times lower than the health benchmark (Table V) under all exposure scenarios considered. It is unlikely that cobalt content will increase to a level that could present health risk to humans. Nevertheless, cobalt levels in biosolids should continue to be monitored.

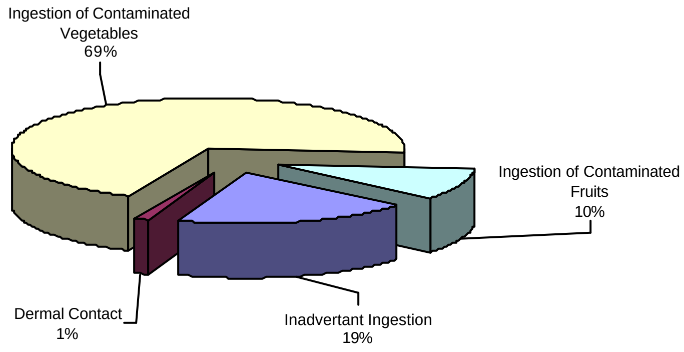


Figure IV Percent Contribution of Each Ingestion/Dermal Exposure Pathway to Composite (Lifetime) Receptor Cancer Risk due to Arsenic under the Home Use Scenario

Health risk was calculated using the estimated soil concentrations after 25 years of pellet use. If operation and sale of pellets were to continue beyond the 25-year period, further review would be required at that time. A field study to monitor annually the change in soil concentration (e.g. in a park) is recommended to confirm the results of the modelling, particularly if the City plans to continue pellet land application for more than 25 years. Professional gardeners, including City Parks workers, are likely to adhere to the recommended application rate (not exceeding 2.7 tonnes per hectare per year). Since twice the maximum recommended application rate (5.4 tonnes per hectare per year) was assumed in the risk assessment, minimal health risk is expected for pellet use on City land, such as parks and golf courses for 50 years. To discourage other users from overapplying the pellets, it is recommended that pellets be sold at a reasonable market price.

Human Health Risk from Exposure to Biological Agents

The assessment of biological risks is more difficult than assessing chemical risks for which there are well-developed guidelines on how to conduct the assessment and health benchmarks against which to assess risk. There are no established guidelines for conducting assessments of biological risks from environmental exposure to biological agents and no clear definition for acceptability as to what level of exposure constitutes a health risk and what level is of negligible or no risk. Given that the science of assessing biological risks is still under development by the scientific community, the risk from exposure to pathogens as a result of pellet use has not been calculated. Rather, the study focussed on the effectiveness of the pelletization process to destroy biological agents of potential concern. The analysis was hampered by the lack of detailed process data, limited knowledge and understanding of individual strains present in the biosolids and their pathogenic or toxigenic potential, and limited available literature.

The pelletization technology used by the City of Toronto produces biosolids pellets by evaporating moisture from digested dewatered biosolids cakes using indirect heat (Seghars Keppel, undated). The wet biosolids cake enters the enclosed dryer from the top onto a heated tray and passes over each of the 17 trays before reaching the bottom. The dried biosolids nuclei are coated with wet biosolids each time they are recycled through the dryer for an average of five to seven passes.

In the United States, biosolids are classified based on certain quality characteristics. To qualify for Class A designation, biosolids must meet specific process, pathogen content and monitoring requirements[9]. The pelletizer manufacturer (Seghars Keppel, undated) asserts that the pelletization process at ABTP meets the USEPA requirement for Class A biosolids. If this is true, since the pellets also meet the USEPA chemical pollutant concentration limits, unlike

[9] To be qualified for Class A designation, biosolids must meet specific process, pathogen content and monitoring requirements (USEPA, 1999). The objective is to reduce pathogen content to below detection limits for *Salmonella sp*., enteric viruses and viable helminth ova (a parasite pathogen). The microbial agents must be measured at the time the biosolids are used or disposed, or prepared for distribution. Class A biosolids must meet one of two requirements: either less than 1,000 most probable number (MPN) faecal coliforms or less than 3 MPN *Salmonella sp.* bacteria per 4 grams total solids (dry weight basis). Processes that involve heat treatment must also meet specific time-temperature requirements.

Class B[10] biosolids, they can be distributed in the United States without restriction. This does not mean that there is no risk from biological agents within the materials (see below).

Microbial Agents

The literature data suggest a minimum process time of 60 to 90 minutes at a temperature of 80º C in order to achieve the destruction of most pathogens (Mocé-Llivina *et al.* 2003; Springthorpe and Sattar, 2004). The pelletizer specifications include the indirect application of dry heat at 110 to 115 °C. The precise number of cycles each pellet goes through inside the pelletizer is highly variable in a continuous flow through process, and can be as little as a single pass. The heat applied is dry heat, but since the biosolids cake has high water content, the humidity could be near 100% inside the dryer. Moist heat requires a lower temperature than dry heat to inactivate pathogens. The limited information suggests that the pelletization process can potentially meet the USEPA process requirement for Class A biosolids. But no confirmatory data on humidity were available and the internal pellet temperature is not known. Follow-up monitoring of the pelletizer or a similar design pelletizer in full operation should be used to verify the humidity, temperature and effectiveness of the process.

Vegetative bacteria are used in the United States to classify biosolids. Class A biosolids should have <1000 MPN (most probable number) of faecal coliforms or < 3 MPN of *Salmonella sp.* per 4 grams of total solids. Most pathogens, including enveloped viruses such as SARS coronavirus, would probably be destroyed when pellets meet Class A specification as defined based on the level of vegetative bacteria, however, there are some pathogens that are more resistant to heat.

Human enteric viruses cannot multiply and will decline in number in the environment. Enteric viruses vary in resistance to heat. If they are shown to be present before treatment, the density of enteric virus in a Class A biosolids after treatment must be less than 1 PFU (plaque forming unit) per 4 grams. The Class A treatment at 80 °C should reduce viruses by more than 99.99 %. Virus numbers in pellets are likely to be small, if they are present at all, but their content cannot be verified at present, as they have not been monitored for. The minimal infectious dose for viruses is extremely small and could be a single infectious virus particle.

[10] Class B biosolids are treated sewage sludge with reduced pathogen content, demonstrated by a faecal coliform density of 2 million MPN per gram total solids (dry weight basis) (USEPA, 1999). US EPA (1999) requires site restrictions for land application of Class B biosolids.

The pelletization process appears to provide the conditions for effective destruction of micro-organisms. However, additional monitoring is needed to confirm this capability. Faecal coliform is a suitable indicator organism for treatment efficiency, but may not be ideal as an indicator for public-health hazard (NRC, 2002). Some pathogens are hardier than faecal coliform. For example, some bacteria and protozoan parasites form spores that are extremely resistant to inactivation by many physical and chemical agents. Conducting routine monitoring for bacteria and phages could provide additional assurance for effective destruction of microbial agents. Phages are considered suitable indicators for human enteric viruses as they are more heat resistant and easier to handle (NRC, 2002). The pellets should be routinely monitored for selected pathogens until a sufficient history confirms the suitability of monitoring only certain parameters. This is especially crucial because the available methods and information are not adequate to quantify risks to toddlers contracting infectious diseases from ingestion of pellets while playing in the park and on the lawns at home. This scenario is unlikely to happen except when pellets are spread on bare soils since the pellets normally migrate down through the grass foliage to the surface of the soil or thatch layer and are not readily available for children to play with.

One potential risk from biosolids aerosols (airborne particles) arises from endotoxins on the outer cell wall of some bacteria, whether they are pathogens or not. Endotoxins can cause a variety of inflammatory responses, exacerbate existing allergy and asthma symptoms, and thus increase the risk to infection (Reed and Milton, 2001; Holla *et al.* 2002; Pirie *et al.* 2003). The pelletization process is unlikely to provide the needed conditions to destabilize the endotoxin. However, the dust fall from the pellets is expected to be low as long as the pellets remain dry and thus not likely a concern for the general public.

The pelletization process may not deactivate some biological entities in the biosolids pellets. Exposure to such entities increase with frequency and duration of handling, as well as quantities used and therefore would be greater for workers than for residents. Given the increased contact time for workers routinely handling large quantities of pellets, some degree of care generally used for handling fertilizers is expected to be sufficient to reduce exposures to such entities during handling to below the level of concern.

The risks from moist pellets are slightly different. If pellets are exposed to water/moisture, they may break down more readily into dust upon handling. A relative moisture content around 9% has been reported to be sufficient to initiate microbial activity (Long *et al.* 1998). Such activity can occur if the drying is incomplete. Therefore, it is important that the pelletizer is operated properly according to design specifications to achieve the desired moisture content. Routine monitoring of pellet moisture content is advisable.

Rewetting biosolids pellets prior to land spreading could also permit some pathogen regrowth. The biological activity initiated can then contribute to a self-heating phenomenon that is sometimes observed. The biosolids dust with high organic content can burn if exposed to an ignition source (OSHA, 1995). Dry storage conditions would prevent these types of problem. Therefore, it would be prudent to review storage and handling issues for pellets and put in preventative measures to reduce the chance of microbial regrowth and smouldering prior to restarting pelletization of biosolids in Toronto. Pathogen regrowth has also been observed following land application after rainfall (NRC, 2002).

To further ensure the safety of pellet use, it is best that pellets be distributed commercially only after the pelletizer consistently produces pellets of the required quality. A mechanism has to be in place that provides assurance that the necessary processing has taken place. A contingency plan and/or emergency response procedures to address pelletizer malfunction related issues, including distribution and product recall should also be part of the biosolids program.

Prions

There are infectious biological agents, such as prions, that are not living organisms. Diseases such as transmissible spongiform encephalopathies (TSEs) are generally associated with normal cellular prion protein that has become infectious due to a conformational change (Prusiner, 2000). TSEs include scrapie, bovine spongiform encephalopathy (BSE, or "mad cow disease) and chronic wasting disease (CWD) in animals and several versions of Creutzfeldt-Jakob disease (CJD) in humans.

While there is no evidence that TSE prion proteins are shed in faeces or urine (USEPA 1999), blood components have been found to carry infectivity during the incubation and clinical phases of TSEs (Brown *et al.* 1999, 2001; WHO, 2001). Though transmission of TSE by blood transfusion has been demonstrated in experimental studies with sheep (Hunter and Houston, 2002; Hunter *et al.* 2002), actual transmission by this route in humans is suspected but not proven in two cases in Britain in 2003 (Llewlyn *et al.* 2004; BBC news, 2004)). Transmission has also been established in humans for ingestion and invasive medical and surgical procedures (Brown, *et al*. 2001).

While the possibility of prion disease agents replicating in the natural environment is unknown and probably remote (Gale *et al.* 1998), some evidence exists for the survival, though much reduced, in soil/pasture of the infectious prion associated with scrapie (Brown and Gajdusek, 1991). The current understanding of the conditions necessary to deactivate the infectious prion protein suggests that the process by which biosolids pellets are produced would not alter the infectivity appreciably (Biogas Works, 2001). The diseases are extremely rare, and no “outbreak” of TSE has occurred among humans in Canada. However, as with most countries, Canada has a (known) cause-specific mortality rate for “spontaneous” CJD of approximately one per million population per year (Prusiner, 2000).

The potential risk for exposure to these biological entities through biosolids pellets is unknown but likely low. Nonetheless, precautionary measures exist to prevent biosolids from acting as a vehicle for transmission of prion diseases. Given it is unlikely that the sewage treatment or pellet production processes can effectively deactivate prions, adopting measures to prevent the entry of prions into the sewer system is advisable. Precautionary steps can be taken to restrict discharge of untreated blood or blood products into the sewer systems. Policies similar to those in the United Kingdom regarding abattoir operation (Gale and Stanfield, 2001) could also be introduced. In the United Kingdom, any animal showing BSE symptoms has to be subject to testing of the brain stem (Gale and Stanfield, 2001). Animals that test positive are incinerated rather than being slaughtered. Other protective measures include banning disposal of animal organs that are known to have the potential to carry infectivity (e.g. brain and spinal tissues) into the sewer system and requiring fine screens to be installed across drains in abattoirs to prevent fine particles from entering the sewers.

Ecological Risk

Ecological risk assessment (ERA) is a process that evaluates the likelihood that adverse environmental effects may occur, or are occurring, because of exposure to one or more stressors. Chemicals present in pellet-amended soil are the stressors considered in this report. For some chemicals (such as arsenic, lead and cobalt), the bioavailability from soil is higher in acidic soils. However, soils in Southern Ontario are generally not acidic (MOE, 1993; Hoffman *et al.* 1964; Chapman and Putnam, 1984).

The assessment was carried out for a set of ecological (non-human) receptors deemed representative of species in the Toronto area that are important to the human population. The selection of potential ecological receptors (also known as valued ecological components or VECs) was based on a review of the intended and likely uses of pellets on private and public property in the City of Toronto or on landfills, and of the biota typically found in the Toronto area. Only soil and soil-based exposures were assessed in the selection. Table VIII summarizes the valued ecological components selected for this assessment.

The scenarios selected for evaluation were the Home or Recreational Use Scenario and the Landfill Use Scenario.

Ecological risk assessment for wildlife and pets was conducted for the scenario involving the use of pellets on lawns but not on gardens as pellets applied to gardens are incorporated into greater depth than on lawns. Given that the land area reserved for home gardens is limited, the gardens would not form a large or continuous habitat for wildlife and pets.

The Landfill Use Scenario was not considered for the evaluation of toxicity to plants and soil organisms (see previous section) because the chemical levels are much lower than in the other scenarios.

Table VIII: Summary of Valued Ecological Components Selected

Receptor Type	Selected VEC[a]
Plants and soil invertebrates	Screening assessment only
Domestic pet – Carnivore	House cat
Domestic pet - Omnivore	Dog
Mammal - Herbivore	Meadow vole
Mammal – Carnivore	Masked shrew
Mammal – Omnivore	Racoon
Mammal – Carnivore	Red fox
Fowl – Carnivore	American Robin
Fowl – Carnivore	Red-tailed hawk

a. VEC = valued ecological component.
b. Omnivore = animal that feeds on both animal and plants.
c. Carnivore = flesh eating animal.
d. Herbivore = animal that feeds on plants only.

Plant Toxicity

A preliminary qualitative assessment was conducted to evaluate the potential for impact on plant life and soil organisms. This assessment is considered appropriate in light of the intended use of pellets as a nutrient-containing soil supplement. The levels that could accumulate in soil (summarized in Table III) after 25 years of pellet use were compared to the ecotoxicity values developed by MOE (1996b) and the Canadian Council of the Ministers of the Environment (CCME, 1999) for the protection of plants and invertebrates.

For most of the chemicals, the soil levels after 25 years of pellet use at twice the maximum recommended application rate (i.e. 5.4 tonnes per hectare per year) were less than the relevant MOE and CCME ecotoxicity criteria. For three of the metals evaluated (copper, selenium and zinc), the estimated concentrations in soils amended with pellets in the top 5 cm of soil were found to be greater than either one or both of the guideline criteria (Table IX). The soil levels were well below the MOE ecotoxicity criteria for both selenium and zinc. The slight exceedance of the CCME ecotoxicity criteria, particularly for selenium, is unlikely to be a concern. The exceedance of both criteria for copper is more significant. The copper soil level was expected to exceed both MOE and CCME criteria after 25 years of pellet application, but only the CCME ecotoxicity criteria after 10 years of pellet application on lawns.

Table IX: Ecotoxicity of Pellet-Amended Soil to Plants or Invertebrates for Selected Metals

Soil Concentration	Cu	Se	Zn
MOE Ecotoxicity Criteria[a]			
(mg/kg)	225	10	600
CCME Ecotoxicity Criteria[b]			
(mg/kg)	63	1	200
Pellets Amended Soil Concentration Assuming 5 cm depth (Lawns)			
1 year (mg/kg)	39	0.51	82
10 year (mg/kg)	**120**	0.73	150
25 years (mg/kg)	**260**	**1.1**	**260**
Pellet Amended Soil Concentration Assuming 15 cm depth (Gardens)			
1 year (mg/kg)	33	0.49	77
10 year (mg/kg)	61	0.56	99
25 years (mg/kg)	**110**	0.69	140

a. MOE Rationale for the Development and Application of Generic Soil, Groundwater and Sediment Criteria for the Use at Contaminated Sites in Ontario, May 1996, Appendix A.2.2 Table B, coarse texture, residential parkland land use – ecological based criteria.

b. CCME, Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health, 1999, rev. 2002, residential/parkland land use, soil quality guideline for protection of environmental health.

Values in **BOLD** are greater than one or both criteria.

The species that determine the ecotoxicity criteria value may not be normally found in the urban park and home environments. Furthermore, the criteria are developed for regular soil and not pellet-amended soil. Depending on the soil conditions, the presence of biosolids cake in soil has been found to reduce the mobility of some metals in soil in the short term and therefore their uptake into plants (WEAO, 2001).

Although these long-term chemical levels are greater than the ecotoxicity criteria, firm conclusions regarding toxicity cannot be reached based on this preliminary evaluation. A more comprehensive analysis is required using toxicity values based on plants most commonly found in parks and gardens in the Toronto area in order to make firm conclusions on plant or soil organism toxicity. The effect of the presence of pellets in the soil on plant uptake could also be considered.

Wildlife and Pets

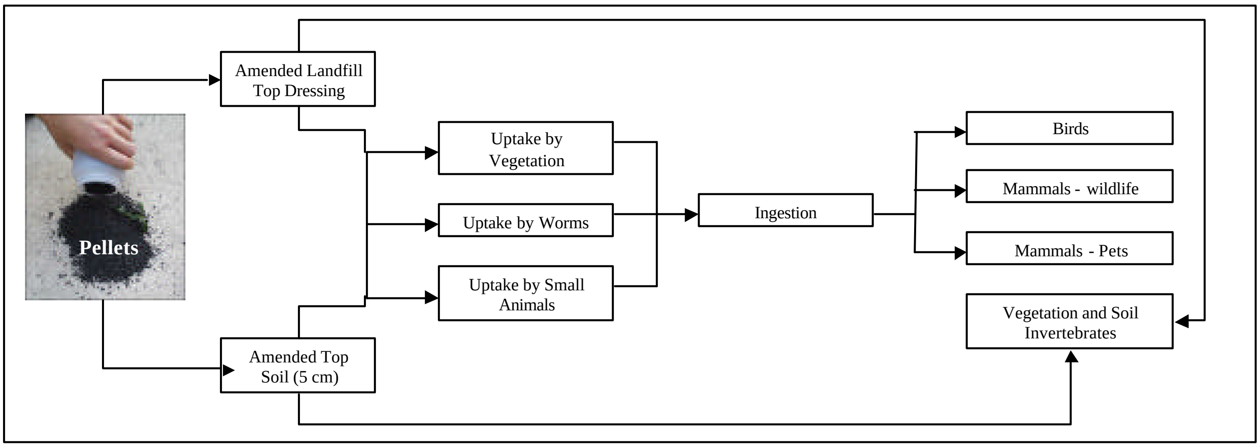
A preliminary quantitative ecological assessment was conducted for wildlife and pets, using an assessment framework (CCME, 1996) similar to the one used for human health. Wildlife ecological receptors or valued ecological components selected for assessment represent species at different strata of the food chain. Receptors include animals that feed on vegetation only (vole), animals that feed on invertebrates such as worms (masked shrew), animals that primarily feed on other smaller animals (red fox), animals that feed on both smaller animals and vegetation (raccoon), birds that eat invertebrates only (American Robin), and birds of prey (red-tailed hawk). Although moles and mice are well known small animal species, meadow voles and masked shrews were selected as representative because they are small burrowing animals common in the area. Burrowing makes them more likely to be exposed to soil pollutants than other small mammals. American Robin was considered to be representative of fowl (carnivore) because of its prevalence in the area and because of its consumption of worms. Consumption of worms makes robins more highly exposed to contaminants in soil than other species (e.g. pigeons, crows or starlings) that are prevalent in the City.

Since pellets are formed from biosolids, chemicals present in pellets are by their very nature not highly soluble since the more soluble chemicals have been removed from wastewater by the process of flocculation. Aquatic effects resulting from dissolved chemicals from pellets on lawns or gardens being transported to watercourses via surface runoff are considered less likely to occur than more direct effects to terrestrial receptors. Aquatic receptors were therefore not evaluated.

Evaluation of the exposure and risk to the chemical entities of potential concern involves an analysis of the exposure pathways, which expose a receptor species to the source. For surface soils and terrestrial receptors, including mammals and birds, exposure to the entities of potential concern resulting from pellet use may occur through the exposure pathways as depicted in Figure V.

The ingestion pathway is most important for wildlife and pet receptors. This assessment considered ingestion of plants or prey species that have accumulated chemicals from the soil as well as ingestion of soil as a result of feeding or grooming.

Figure V: Ecological Exposure Pathways and Receptors



Different assessment endpoints were selected for pets than for wildlife, reflecting the importance of pets to people as individuals.

- Wildlife Assessment Endpoint: Populations of birds or mammals that may be reduced as a result of increased mortality or decreased reproduction because of the constituents of concern in soils.
- Pet Assessment Endpoint: Individual pets that may have increased risk of health effects because of the constituents of concern in soils.

Risks were characterized by calculating ecological hazard quotients. An ecological hazard quotient is the ratio of the estimated exposure level to a benchmark[11]. A hazard quotient less than one indicates that no effects to wildlife at a population level or pets at an individual level are expected. A hazard quotient greater than one does not necessarily imply an adverse effect.

For the home lawn and City parkland scenarios, all hazard quotients calculated are less than one, except for exposure of American robins to chromium III, exposure of domestic dogs and house cats to arsenic, and exposure of house cats to dioxins and furans (Table X). This finding indicates that all the other receptors evaluated are not expected to be at risk for the selected assessment endpoints.

[11] For wildlife, the benchmark was based on the Lowest Observed Adverse Effect Levels or the No Observable Adverse Effect Levels in relation to survival or reproduction. For domestic dogs and cats, the No Observable Adverse Effect Level was used to take into account the special relationship between humans and pets.

For the landfill scenario, all hazard quotients are less than one (Table XI) indicating that no risk to receptors evaluated is expected for the selected assessment endpoints.

In the home use scenario, a hazard quotient of one was estimated for the exposure of dogs or house cats to arsenic, and the exposure of house cats to dioxins and furans. The benchmarks for evaluating risk to house cats and dogs were based on No Observable Adverse Effect Levels for chronic effects (reproduction effects over 3 generations). Since the No Observable Adverse Effect Levels are set at 10 times more conservative values than the Lowest Observed Adverse Effect Levels, hazard quotient values of 1 are considered to indicate no expected risk.

For wildlife, the benchmark was based on the Lowest Observed Adverse Effect Levels or the No Observable Adverse Effect Levels in relation to survival or reproduction. A hazard quotient of three was estimated for exposure of robins to chromium III, should pellets be widely used across their home range. However, taking into consideration that pellets are not likely to be used on more than 60% of the robins' home range, effects to robins are not expected. The American Robin is considered to be more sensitive for this assessment than other bird species in Toronto because of its consumption of worms, which ingest soil. For this reason, the elevated ecological hazard quotient of three estimated for the American Robin is not expected to indicate a potential risk to other bird species.

As illustrated in Table II and Figure IIb, the chromium levels in the biosolids are decreasing over time in the recent years. The drop in concentration is statistically significant from the period 1996-2000 to 20001-2003, corresponding to the enactment of the Toronto revised Sewer Use By-law in July 2000. If the trend continues, the actual chromium concentration in the pellet-amended soil from 25 years of pellet application would likely be lower than the value used for the assessment. Additionally, bioavailability of chromium in soil is expected to be less than the 100% assumed in the assessment. Either of these factors alone would be sufficient to reduce the hazard quotient for robins to below one, indicating that no effect to robins is expected.

Table X Summary of Ecological Hazard Quotients[a] for Home or Park Use Scenario

Constituent	Masked Shrew	Meadow Vole	House Cat	Raccoon	American Robin	Red-tailed Hawk	Pet Dog	Red Fox
PCDD/Fs[b]	0.03	0.002	1	0.4	0.01	0.007	0.9	0.3
PCBs[c]	0.001	0.0001	0.004	0.0009	0.0004	0.00004	0.005	0.0002
Arsenic	0.08	0.06	1	0.1	0.02	0.006	1	0.06
Cadmium	0.01	0.005	0.4	0.3	0.05	0.01	0.4	0.1
Chromium	0.001	0.00005	0.0008	0.0009	**3**	0.4	0.0007	0.0002
Cobalt	0.01	0.005	0.2	0.02	0.006	0.005	0.2	0.01
Copper	0.3	0.4	0.9	0.7	0.1	0.1	0.8	0.8
Lead	0.03	0.008	0.3	0.03	0.2	0.2	0.2	0.03
Mercury	0.07	0.08	0.03	0.07	0.09	0.03	0.03	0.04
Molybdenum	0.1	0.06	0.4	0.1	0.008	0.002	0.4	0.05
Nickel	0.1	0.01	0.3	0.09	0.04	0.02	0.2	0.05
Selenium	0.4	0.3	0.4	0.4	0.1	0.2	0.2	0.7
Zinc	0.2	0.06	0.1	0.1	0.4	0.3	0.05	0.2

a. Ecological hazard quotient = estimated exposure level/benchmark. The benchmark is based on No Observable Adverse Effect Level for house cats and dogs. For wildlife, the benchmark is based on the Lowest Observed Adverse Effect Level or No Observable Adverse Effect Level.
b. Total dioxins and furans, evaluated based on 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin.
c. Total PCBs, evaluated based on Aroclor 1254.

Table XI Summary of Ecological Hazard Quotients[a] for Landfill Use Scenario

Constituent	Masked Shrew	Meadow Vole	House Cat	Raccoon	American Robin	Red-tailed Hawk	Pet Dog	Red Fox
PCDD/Fs[b]	0.003	0.0002	0.1	0.03	0.0009	0.0007	0.1	0.03
PCBs[c]	8×10^{-8}	5×10^{-8}	3×10^{-6}	2×10^{-7}	3×10^{-8}	2×10^{-8}	3×10^{-6}	9×10^{-8}
Arsenic	0.01	0.01	0.09	0.02	0.003	0.0006	0.1	0.007
Cadmium	0.003	0.001	0.1	0.07	0.01	0.005	0.06	0.04
Chromium	0.0002	5×10^{-6}	0.0001	0.0001	0.3	0.06	7×10^{-5}	3×10^{-5}
Cobalt	0.0002	7×10^{-5}	0.003	0.0002	0.0001	8×10^{-5}	0.003	0.0002
Copper	0.2	0.2	0.2	0.2	0.05	0.09	0.1	0.4
Lead	0.003	0.001	0.03	0.003	0.02	0.05	0.01	0.008
Mercury	0.03	0.02	0.002	0.02	0.03	0.002	0.002	0.006
Molybdenum	0.02	0.01	0.08	0.02	0.001	0.0003	0.07	0.009
Nickel	0.009	0.001	0.04	0.007	0.003	0.004	0.02	0.01
Selenium	0.07	0.03	0.1	0.07	0.02	0.09	0.02	0.3
Zinc	0.09	0.02	0.06	0.07	0.2	0.3	0.008	0.1

a. Ecological hazard quotient = estimated exposure level/benchmark. The benchmark is based on No Observable Adverse Effect Level for house cats and dogs. For wildlife, the benchmark is based on the Lowest Observed Adverse Effect Level or No Observable Adverse Effect Level.
b. Total dioxins and furans, evaluated based on 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin.
c. Total PCBs, evaluated based on Aroclor 1254.

Similar to human health risk, ecological risk was calculated using the estimated soil concentrations after 25 years of pellet use. If operation and sale of pellets were to continue beyond the 25-year period, further review would be required at that time. As discussed previously, field study to monitor annually the change in soil concentration (e.g. in a park) is recommended to confirm the results of the modelling, particularly in the event that pellet application were to continue beyond 25 years.

Emerging Issues

Some concerns related to biosolids recycling have come to light in the recent years. Some of these concerns have arisen because of the detection of additional toxic chemicals in sewage or biosolids around the world. Others are due to new evidence indicating potential adverse effects for certain substances that could be present in sewage. Lack of adequate knowledge about things such as the effect of low level exposure to endocrine disruptors has also raised concern among the public.

- Odour

  Odour, a long-standing issue, may affect public acceptance of pellet use because of the lack of prediction of potential impact. Odour detection is very subjective. Although biosolids pellets would be at the low end of a subjective measurement scale of odour unpleasantness, individual tolerance and sensitivity to odours will dictate public acceptance.

- Polybrominated diphenyl ethers

  Polybrominated diphenyl ethers (PBDEs) are a group of flame retardants (totalling 209 congeners) that are used in a wide range of consumer products, such as electrical and electronic components and casings for household appliance and electronic devices (e.g. hair dryers, televisions, computers), furniture upholstery and cushioning, wire and cable insulation (IPCS, 1994). PBDEs have been detected in Southern Ontario sewage sludge at relatively high concentrations (La Guardia *et al.* 2001; Kolic *et al.* 2003). Concern has been raised among the public because of PBDE's physical and chemical similarity to PCBs and their detection in human breast milk (Ryan *et al.* 2002), sediment and wildlife (Wenning, 2002), including those in the Arctic, suggesting efficient long-range atmospheric transport (Environment Canada, 2004). PBDEs have been deemed "toxic" under the Canadian Environmental Protection Act (CEPA, 1999) because the amount entering the environment has harmful effect on ecological receptors (Environment Canada (2004). However, Health Canada (2004) concluded based on a screening assessment that the current exposure level of PBDEs does not pose a risk to humans. Management of ecological risks is expected to be protective of human health.

- Endocrine disruptors

An endocrine disruptor is *an exogenous agent*[12] *that interferes with the production, release, transport, metabolism, binding, action or elimination of natural hormones in the body responsible for the maintenance of homeostasis and the regulation of developmental processes* (USEPA, 1997b). The effects of endocrine disruption have been detected in wildlife including gulls in the St. Lawrence and alligators in Lake Apopka in Florida (Schettler *et al.* 1999), influencing public perception and concern. Major concerns regarding exposures to endocrine disruptors include the timing, level and duration of exposure relative to the developmental stage of the organism (WHO, 2002).

Phthalates and alkylphenol ethoxylates are two of the chemical groups suspected to be endocrine disruptors. Phthalates are widely used as plasticizers to soften and increase the flexibility of plastics. Despite advisories and warnings by regulatory agencies for di-(2-ethylhexyl) phthalate and diisononyl phthalates (Health Canada, 1998a, 1998b; Wilkinson and Lamb, 1999), researchers are still debating the risk of adverse health effects from phthalate.

Alkylphenol ethoxylates are surfactants commonly found in detergents, paints, herbicides and pesticides (White *et al.* 1994; WEAO, 2001; WHO, 2002). Of particular interest are nonylphenol ethoxylates and their degradation product, nonylphenol. Both nonylphenol and nonylphenol ethoxylates have been found in fresh water, sediment, fish and beluga whale tissue, effluents from textile mills, paper mills and municipal treatment plant, sludges, and soil to which municipal sludges had been applied (Environment Canada, 2000). Nonylphenol and its ethoxylates are considered “toxic” under CEPA (1999), because of their levels in the environment and their impact on ecological receptors, including fish, invertebrates and algae (Environment Canada, 2000). Nonylphenol and its ethoxylates have been reported to cause a number of estrogenic responses in various aquatic organisms (Environment Canada, 2000) at concentrations similar to those at which chronic toxicity occurs. Nonylphenol is, however, 100 000 times less potent than the female hormone, estradiol. The relative importance and significance of estrogenic responses in aquatic organisms to humans are not currently well understood.

[12] An agent that originates outside of the organism.

- Linear Alkylbenzene Sulphonates

Linear alkylbenzene sulphonates are surfactants and common ingredients of domestic and industrial detergents. There is little evidence that these chemicals would pose a threat to terrestrial ecosystems. Understanding the human health effects of this group of substances is still premature although de Wolf and co-workers (1998) have concluded that any human health risk as a result of exposure is not expected.

- Pharmaceuticals

A number of antibiotics, prescription and non-prescription drugs and their metabolites have been found in wastewater, municipal sewage treatment plant discharges, rivers and stream waters around the world (Kolpin *et al.* 2002; Ternes, 1998; Hirsch *et al.* 1999; Stumpf *et al.* 1999).

Administration of antibiotics and growth promoters as feed additive in fish and animal farms is an important source of medical substances in the environment. Pharmaceuticals can also enter wastewater stream, mainly through patient excretion in urine or faeces but also through the flushing of medicine down the toilet (WEAO, 2001; Anderson *et al.* 2004).

Most drugs are water-soluble and are not expected to accumulate in sewage biosolids (Alcock *et al.* 1999). Some are lipophilic and therefore can accumulate in the biosolids during sewage treatment, but their more water-soluble metabolites are less likely to end up in the biosolids (Apedaile *et al.* 2002). Once in the environment, these metabolites tend to be transformed back to their parent compounds (Holling-Sorensen *et al.* 1998). Some of the compounds are degraded in either the treatment plant itself or in the soil.

Little is known about the long-term public health risk and ecological risk of ingestion of drugs and their metabolites at levels that are orders of magnitude below therapeutic doses. A review of available risk assessments regarding pharmaceuticals by Apedaile and co-workers (2002) concluded that there was negligible human risk. However, they also recommended further study.

The presence of antibiotics in wastewater has raised concern for the proliferation of drug-resistant strains of bacteria in biosolids and the environment. In 2002, the Committee on Toxicants and Pathogens in Biosolids Applied to Land of the U.S. National Research Council has briefly reviewed this issue and concluded that land applied biosolids (cakes) would not have any substantial potential to alter the prevalence of antibiotic resistance among pathogenic microorganisms. Therefore, it is expected that this would also be the case with pellets.

- Radionuclides

Radionuclides cause cancer in humans; the target organs vary depending on the radionuclide of concern. The Canadian Nuclear Safety Commission is responsible for enforcing federal guidelines that govern the management, discharge and disposal of radioactive materials among universities, pharmaceutical companies, laboratories and others that use them. The Toronto Sewer Use By-law also has restriction on the discharge of radioactive materials into the sewer system. Though a number of radionuclides used in medical testing or pharmaceuticals might end up in the sewers, they are usually short-lived (i.e. they decay rapidly to stable material) and would not persist in the wastewater system or the biosolids (WEAO, 2001). This suggests that radionuclei are not likely to be present in pellets at levels that would cause concern.

- Unregulated metals/inorganics

Metals/inorganics other than those regulated by the Fertilizers Act and MOE guidelines, including aluminium, antimony, beryllium, boron, fluoride, silver, strontium, thallium, tin, vanadium, could be present in biosolids. The issue regarding these unregulated substances have been reviewed previously (WEAO, 2001; Apedaile *et al.* 2002). In general, these constituents in biosolids have received little research attention and data on their levels in biosolids are limited. Nevertheless, regulatory agencies are assessing the need for setting limits for them.

The methods for characterizing the chemicals identified are not well developed for biosolids and pellets. In some cases, the analytical methods to reliably measure these chemicals are still under development. For this reason, these chemicals are not included in the routine biosolids monitoring program. To reduce the risk from exposure to these chemicals from beneficial use of biosolids, Toronto restricts the discharge of many of these chemicals, including radionuclides, into the sewer system under its Sewer Use By-law. Besides setting strict discharge limits for many known endocrine disruptors including phthalates, nonylphenol and ethoxylates, the By-law also requires institutions and industries that discharge these chemicals to submit pollution prevention plans to the City. Health Canada, which is responsible for regulating pharmaceuticals, is considering development of a cradle to grave approach for pharmaceuticals.

Conclusion

The pelletization process as designed is expected to destroy most pathogens and produce pellets of similar quality as those classified by United States Environmental Protection Agency as Class A biosolids. Class A biosolids can potentially be distributed in the United States without restriction. However, some biological entities in the biosolids pellets may not be totally deactivated by the pelletization process. Exposure to such entities increase with frequency and duration of handling, as well as quantities used, therefore exposure would be greater for workers than for residents. Little risk is expected from occupational exposure to pellet use for workers who work in the landfill and recreational areas, such as parks, golf courses and gardens.

Residents are not expected to experience health effects from inhaling dust and vapours, and ingesting soil arising from the use of pellets at home and in recreational green space such as parks and golf courses. No risk is expected for residents who use Toronto pellets at work in parks, recreational green spaces and horticulture. There is minimal risk associated with arsenic from ingestion of vegetables and fruits grown in pellet-amended soil in the home garden. Pellets spread on leafy lawns and turf areas are not readily available to children less than five years old, however, those left on patches of bare soil with no foliage or vegetation coverage can be accessible for ingestion. While no risk from chemical substances is expected, current methods and information are inadequate to quantify risks to these children contracting infectious diseases from ingestion of pellets.

Use of pellets as landfill topdressing, in recreational green spaces and in homes is not expected to pose a risk to wildlife and pets such as domestic cats and dogs. Wildlife species evaluated include those that are representative of species that feed on vegetation only, animals and birds that feed on invertebrates such as worms, animals that primarily feed on other smaller animals, animals that feed on both smaller animals and vegetation, and birds of prey. Although the assessment suggests a possible small risk for the American robins due to chromium exposure, the assessment has not accounted for the continuing decrease in the level of chromium in Toronto biosolids nor for the fact that it is unlikely that robins feed exclusively in areas where pellets are spread regularly. Therefore, use of pellets is not expected to result in adverse impacts on robins or other bird species.

The screening assessment of plant and soil organism health indicates that the levels of copper in soil were higher than MOE and CCME ecotoxicity guidelines when the pellets accumulate in the top 5-cm of soil (parks, golf courses and lawns). Copper levels were also higher than CCME ecotoxicity values when pellets were mixed within the top 15-cm of soil (gardens). A preliminary screening exercise is useful only for identifying areas that need more detailed analysis and areas that do not. No conclusion can be made on whether adverse effects on plants or soil organisms may actually occur, but more detailed investigation is recommended.

All the analyses were conducted using the estimated soil concentrations after 25 years of pellet use. If the operation of the pelletizer and sale of pellets were to continue beyond the 25-year period, further review would be required at that time. The analysis assumes pellet application at double the maximum recommended application rate. Since professional gardeners, including City Park workers, are likely to adhere to the recommended application rate, minimal risk is expected for pellet use on City land, such as parks, horticultural areas and golf courses for 50 years.

Recommendations

The following recommendations address areas where there is uncertainty regarding potential for adverse effects:

(1) Works and Emergency Services to:

(a) conduct follow-up monitoring of the pelletizer or a similar design pelletizer in operation to ascertain the pellet temperature, process time, humidity and confirm the effectiveness of the process;

(b) conduct routine monitoring for more suitable indicator bacteria and phages by measuring reductions as a result of the pelletization process until a sufficient history confirms the suitability of monitoring representative parameters and moisture content to ensure pellet quality; the testing to be done also at the time of distribution to provide additional assurance for minimal risk from microbial agents;

(c) monitor the levels of the 11 metals, polychlorinated biphenyls, dioxins and furans in pellets and conduct trend analysis periodically to ensure that the quality of the pellets is maintained or improved;

(d) in consultation with the Medical Officer of Health, assess the feasibility of extending the routine monitoring program to include additional organic compounds and other unregulated metals, in particular those identified in this report; and once adequate data are available, evaluate the significance of their impacts on human health and the environment;

(e) develop a contingency plan for unforeseeable events that may result in the unexpected production of pellets that are unsafe for planned uses, such as pelletizer malfunctioning or pellets not meeting specification. The contingency plan should include an alert system which serves as a trigger for specific actions in a timely manner to halt product distribution;

(f) conduct a field test on the potential for pathogen regrowth in the soil at the time of pellet use;

(g) conduct a review of storage issues for pellets including the potential for pathogen and microbial regrowth and smouldering so as to put in the necessary precautionary measures prior to restarting pelletization of biosolids in Toronto;

(h) market pellets as a product only after the pelletization facility can achieve pellets of intended quality, approximately 3 mm and a solid content of 97% (3% water content);

(i) include in the label precautionary instructions on proper storage of pellets, including advice on preventing easy access to pellets by young children;

(j) avoid the use of pellets on lawns and park turf with extensive patches of bare soil, where pellets might become accessible to young children, until that time when monitoring of suitable indicator bacteria and phages confirms the absence of microbiological risk from accidental ingestion of pellets;

(k) conduct, in consultation with Parks and Recreation, controlled field test to provide added assurance that the pellets break down in a timely fashion so as to be useful as soil amendment and fertilizer;

(l) conduct, in consultation with Parks and Recreation, controlled field tests to monitor concentrations of the ‘entities of concern’ identified in this report in pellet-amended soils over time in the park to confirm the results of the modelling exercise;

(m) conduct another review on pellet use prior to making a decision to continue pelletization in 25 years time; and

(n) work towards amending the Toronto Sewer Use By-law to restrict the disposal of waste pharmaceuticals and untreated blood and blood products, including those from funeral homes and animal slaughter houses (abattoirs), into the sewage system;

(2) Canadian Food Inspection Agency and the Ontario Ministry of Agriculture and Food to:

(a) ensure implementation of policies to prevent animals showing symptoms of mad cow disease or similar illnesses from being slaughtered in abattoirs, and to dispose of them in an appropriate manner; and

(b) introduce policies to ban animal organs known to have the potential to carry prion infectivity, such as brains and spinal cords, into the sewers, and prescribe fine screens across drains in abattoirs;

(3) the Ontario Ministry of the Environment to restrict the discharge of untreated blood and blood products into the sewer system, including those from funeral homes and animal slaughter houses (abattoirs); and

(4) Canadian Food Inspection Agency to establish standards for maximum permissible levels of chromium and copper in fertilizers; to facilitate this process, more comprehensive studies, including laboratory-based research, are needed to address the potential bioavailability, phytotoxicity and/or ecotoxicty resulting from long-term use of pellets in urban parks and residential properties.

Our risk assessment finds that golfers are not expected to experience health risk if Toronto pellets were used in golf courses. However, Ontario legislations prohibit the use of “non-agricultural materials”, which include Toronto biosolids pellets, in golf courses. Further, although the Ontario regulatory framework provides for non-agricultural uses of biosolids, the regulatory processes have not been worked out for many of these uses. The following recommendations address some of these regulatory barriers to pellet use. It is recommended that Works and Emergency Services:

(1) submit a proposal to the Ministry of the Environment and the Ministry of Agriculture and Food requesting that Section 97.(0.1) of Regulation 267/03 be amended to permit land application of further processed biosolids pellets to golf courses; and

(2) consult with Ontario Ministry of the Environment to explore non-agricultural uses for the pellets.

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