Sydney Tar Ponds: Some Problems in Quantifying Toxic Waste

EDWARD FURIMSKY
IMAF Group
184 Marlborough Avenue
Ottawa, Ontario,
Canada, K1N 8G4

ABSTRACT / Information on the type and amount of hazardous and toxic waste is required to develop a meaningful strategy and estimate a realistic cost for clean up of the Sydney Tar Pond site which is located on Cape Breton, in the province of Nova Scotia, Canada. The site covers the area of the decommissioned Sysco (Sydney Steel Corporation) plant. The materials of concern include BTEX (benzene, toluene, ethylbenzene, and xylenes), PAH (polycyclic aromatic hydrocarbons), PCB (polychlorinated biphenyl), and particulates laden with toxic metals, such as arsenic, lead, and others. The originally nontoxic materials such as soil, blast furnace slag, and vegetation, as well as surface and ground waters, which were subsequently contaminated, must also be included if they fail tests prescribed by environmental regulations. An extensive sampling program must be undertaken to obtain data for an accurate estimate of the waste to be cleaned and disposed of. Apparently, 700,000 tons of toxic waste, which is believed to be present on the site, may represent only a fraction of the actual amount. The clean-up of the site is only part of the solution. Toxic waste has to be disposed of in accordance with environmental regulations.

The Sydney Tar Ponds are situated at tidewater in Sydney, Nova Scotia, on Cape Breton in Canada (Figure 1). This site covers an area of about 400 has and is adjacent to the Muggah Creek estuary. Contamination of the site and surrounding areas resulted from approx. 90 years of steel plant operations with the adjacent coke ovens that began in early 1900s. Since 1967, operation of the plant was assumed by Sysco, a provincial crown corporation with substantial subsidies from the federal government. Information suggests that during the period of plant operation, awareness of environmental, safety and health issues by plant operators and workers was at a minimal level. These issues attracted some attention in the early 1970s, after it was determined in the US Steel producing plants that the exposure of workers to the emissions from coke-making is a serious health hazard. In spite of these findings, operation of the coke ovens continued until 1988. Several studies published by the National Cancer Institute of Canada confirmed a high mortality rate in Sydney compared with other parts of the province. On the national scale, the mortality rate is the highest in Nova Scotia, followed by the neighboring provinces (NCIC 1997). For these reasons, the Sydney Tar Ponds have been attracting the attention of the general public, as well as Canadian and foreign environmentalists and governments. This may be North America's largest toxic waste site.

The gaseous toxics were emitted from both blast furnaces and coke ovens and affected the air quality in the region during the decades of plant operation. Little information is available on this issue because the air quality in the region was not monitored on a regular basis. It is believed that the emitted gaseous compounds were dispersed in the air and presently do not contribute to the pollution, in contrast to the liquid, semiliquid, and solid emissions from coke-making, which are currently the main cause of site contamination. Most of the liquid, consisting of BTEX, semiliquid tars consisting of PAHs, and toxic metals emitted during the plant operation, was disposed of either on the site or in Muggah Creek. It was stated that tar disposal into Muggah Creek was performed on a regular basis (Gordon 1997). Moreover, little attention was paid to the particulates deposited on the plant and surrounding areas or to disposal of the PCBs. This suggests that safe methods for storage and/or disposal of the other hazardous wastes were also not used. In fact, there is no information to suggest that any waste management system was in place during most part of the plant's period of operation. It is frequently reported in the media that the site contains over 700,000 tons of toxic sludge, of which an estimated 50,000 tons are contaminated with PCBs. It is not clear how this estimate was made. Therefore, an attempt will be made to verify the validity of this estimate. For this purpose, the available data on the properties of typical metallurgical coals, as well as information on the amount of the emitted particulates, will be used (Holloway and others). It is believed that no reasonable strategy for clean-up can be developed without a thorough assessment of the site, with the aim
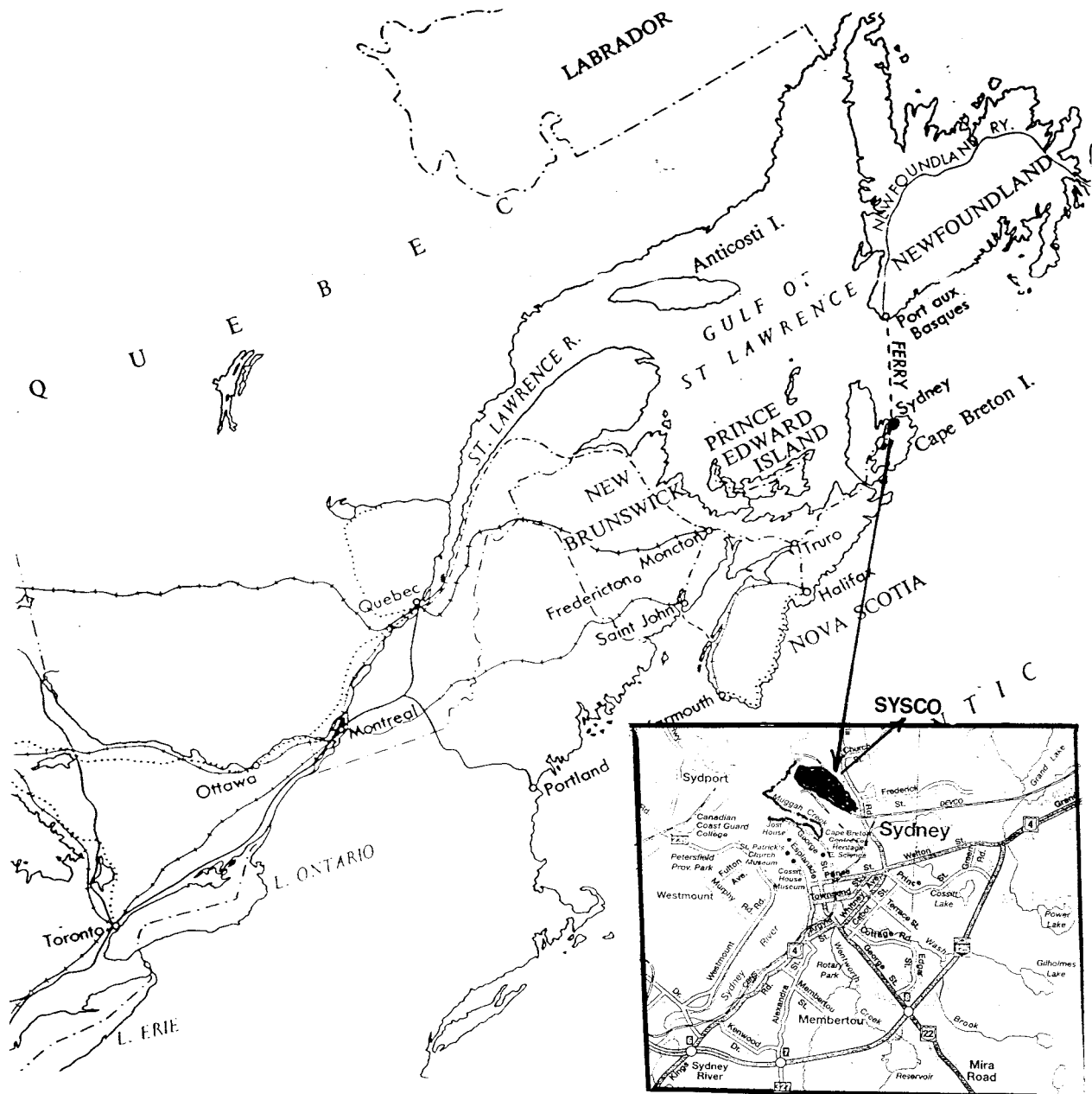
Figure 1. Location of Sydney Tar Ponds.

to obtain a detailed inventory of the toxic waste produced at the site.

The first attempt to clean the site (in the late 1980s) involved construction of a fluidized bed reactor for incineration of the tar. The rationale for selecting this system is not available. It is well known that temperatures in fluidized bed systems are not high enough to achieve complete incineration of PAHs and PCBs and the attempt was unsuccessful. Subsequently, a joint action group (JAG), comprising governments and citizen groups, was put together to develop a strategy for dealing with the problem. The JAG established a database comprising various reports dealing with the issue which is part of the Report on Material Sampling (RMS). This may represent the most extensive information available on the problem and can be accessed via the Internet (www.muggah.org). For example, it provides an inventory of items, such as buildings, tanks, stacks, lagoons, etc., which are still on the site. Normally, such items are removed from the site as part of the plant decommis-

Table 1. Concentrations of regulated metals in TCLP leachates (ppm)[a]

Element	Regulatory level	Solid		
		A	B	C
Arsenic	5	53	(0.23)	0.03
Barium	100	(0.05)	(0.05)	2.4
Cadmium	1	ND	(0.001)	0.01
Chromium	5	(0.016)	(0.016)	0.01
Lead	5	0.3	(0.003)	0.07
Mercury	0.2	ND	ND	0.05
Selenium	1	(0.005)	(0.005)	0.02
Silver	5	ND	(1.0)	0.02

[a]ND, nondetectable. Results in parentheses represent detection limits of the analytical method

sioning. This paper is based on information from the JAG files as well as on some results that are available in the scientific literature. The last report published by JAG was not used for the purpose of this study because the original intention to make it accessible via the Internet was changed. Very useful information on the issue was provided by the Sierra Club (SC). This information can be accessed via Internet (www.sierraclub.ca/stp/stp-factsheet.html), as well. Of particular importance is the critical review of the report prepared by CanTox Environmental for the Nova Scotia government concerning human health risk assessment of the Frederick Street area. This area was inhabited until very recently, in spite of the significant contamination.

Identification of Hazardous and Toxic Waste

There are several criteria according to which waste is declared hazardous, i.e., it must be capable of releasing, by any means, an amount of hazardous constituents that exceeds regulatory levels. The constituents can be either organic or inorganic in nature. Substances to be considered are listed in the US Federal Register (US EPA 1990) published by the US Environmental Protection Agency (EPA) and the User's Guide to Hazardous Waste Classification published by Environment Canada (EC 1993). In the case of the Sysco plant, the most important organic species include phenols, aromatic compounds, PAHs, PCB, as well as nitrogen- and sulfur-containing compounds. Inorganic acids, sulfides, and cyanides are among the toxic inorganic species. The list of potentially toxic metals is rather extensive and includes arsenic, lead, cadmium, mercury, selenium, chromium, etc. A complete list of the metals can be obtained from the Federal Register (USEPA 1990) and/or User's Guide (EC 1993). Waste is subjected to well-established procedures before it can be classified one way or the other. The toxicity characteristics leaching procedure (TCLP) developed by US EPA and de-

scribed in detail in the Federal Register (US EPA 1990) has been widely accepted for characterizing solid wastes to determine appropriate methods of handling, storage, and disposal. This method involves 18 hours of shaking a sample in a solution under standard conditions approaching that in the environment. In this case, pH was controlled by the sodium acetate buffer. This is followed by filtration of the solid and determination of the content of the regulated metals and organic compounds in the filtrate. Examples of data obtained by this method are shown in Table 1 (Furimsky 1996, Chung and others 1996). The first column shows the regulatory levels of the selected elements. If these levels are exceeded in the filtrates obtained according the TCLP method for only one element, the solid has to be declared as toxic. Therefore, solid A in Table 1 is toxic, whereas solids B and C are not. The list of organic compounds and their regulatory levels, which are also determined in the TCLP filtrates for the same purpose, is quite extensive as well (US EPA 1990; EC 1993). Similarly, if the regulatory level is exceeded for only one organic toxic, the waste has to be declared hazardous. No information could be found to indicate that, in the case of the Sysco plant, characterization of the solid waste according to the TCLP methods was undertaken.

Waste has to be characterized according to the hazardous characteristics described by the regulations (US EPA 1990, EC 1993). In the case of the Sysco plant, a number of hazardous characteristics should be considered. Thus, a waste can be declared hazardous if it fails the tests for ignitability, corrosivity, and reactivity. For example, coal dust covering some parts of the plant area may fail the ignitability test. Of particular importance is the liberation of toxic species when contact with water and air occurs. It is also important to ensure that during prolonged storage, the originally nonhazardous waste is not capable, by any means, of yielding a toxic material at a later stage. Secondary contamination may occur during prolonged storage by admixing toxic

waste in contact with and/or on top of nontoxic material. In the case of the Sysco plant, the uncontrolled disposal of the potentially toxic waste occurred over many decades. This suggests that the nontoxic material could have been contaminated by toxic species leaching out from the former. In the absence of any toxic waste management system in the Sysco plant, the probability of secondary contamination was rather high. In Canada, User's Guide (EC 1993) lists a number of methods for handling toxic wastes. An appropriate procedure has to be selected from the list according to the identified toxic nature of the waste. Because environmental regulations are still evolving, selection of suitable methods for storage and disposal may require consultation with experts in the field.

It is evident that the leachability and hazardous characteristics of the waste in the Sysco plant and surrounding area were not determined according to the prescribed procedures. It is essential that a series of properly selected samples be subjected to such evaluation before developing a strategy to deal with the Sydney Tar Ponds issue. It is unlikely that this problem can be successfully solved without such information.

Characterization and Estimation of Emissions

The types of emissions created during steel- and coke-making, the latter of which is usually an integral part of the former, are generally known. However, estimating the total amount of emitted solids, liquids, and gases during the entire period of operation of the Sysco plant is a rather difficult task. Apparently, records from some 90 years are either unavailable or incomplete. Both blast furnaces and coke ovens contributed to the emissions, although in different ways. In the following discussion, the focus will be on the emissions that affected air quality during the plant operation, as well as those that might be the main cause of the current contamination of the site.

Emissions from Blast Furnaces

SO_x and NO_x were the main gaseous emissions from the blast furnaces. It appears that until 1972, little attention was paid to this issue. At that time, it was estimated that the daily emissions of SO_2 exceeded 21 tons, while NO_x was not measured at all. Some SO_2 was captured in situ by limestone addition. Since the amount of emitted SO_2 correlates with the amount of iron produced, an estimate of the total SO_2 produced can be made from the total iron production. It was projected in 1972 that the daily steel production would approximately double by 1975. With this increase, the daily SO_2 emission could have reached about 26 tons,

but only in the case that the air pollution equipment was installed. It is obvious that after many decades of blast furnace operation without any pollution control, the adverse effects caused by acid rain on the plant and surrounding areas might be significant.

The solids emitted during iron production include the dust from handling and moving iron ore. However, iron ore is not classified as a hazardous and/or toxic material unless some regulated elements were present. Therefore, contamination of the surrounding area with iron ore dust may not constitute any hazard. During iron production, the non-iron-containing compounds (e.g., predominantly SiO_2 and Al_2O_3 oxides) present in the ore are converted to slag. Slag is a glassy and nonleachable material that can be disposed of safely. It can also be utilized as a construction material. The amount of slag produced depends on the grade of the iron ore and the ash content in the coke. The calcium present in the limestone added to the blast furnace reacts with SiO_2 and Al_2O_3, as well as the other noniron components of the ore. It was established that calcium will convert some priority elements (e.g., arsenic) into nonleachable compounds (Lecuyer and others 1996). It is, therefore, unlikely that slag disposed from the blast furnace was a source of contamination. In fact, the properly managed slag disposal can be an important part of site house keeping. Because of its innocuous nature, no attempt will be made to estimate the amount of slag produced. It should, however, be stated that secondary contamination of the originally nonhazardous slag could have occurred because waste disposal on the site was not properly managed. For example, decades of deposition of the coke oven particulates, laden with regulated metals, could have contaminated the slag, and regulated metals leached out from the toxic waste could have contaminated the nontoxic slag. Therefore, an evaluation of slag samples using the TCLP would be required to confirm, with certainty, its nontoxic character.

Emissions from Coke Ovens

The contribution of the emissions from coke-making to the site contamination was much more significant than that of the blast furnaces. During coke oven operation, the air quality was affected by toxic gases such as hydrogen sulfide (H_2S), carbon disulfide (CS_2), carbonyl sulfide (COS), ammonia (NH_3), hydrogen cyanide (HCN), arsine (AsH_3) and carbon monoxide (CO). It is generally known that these toxics are formed during the coking of coal (Chen and others 1999). Exposure of the coke oven workers to AsH_3, one of the most toxic substances, was already reported (Hockeny 1970). Some exposure to hydrogen chloride (HCl)

could have occurred as well. There is no information to suggest that the content of these compounds was monitored during coke oven operation although some symptoms observed in the workers, which are described in the JAG reports, are consistent with exposure to some of these toxics (Anon, 1994). The extent of contamination of the environment and the potential exposure of the general public to these toxics during operation of the coke ovens cannot be assessed without obtaining details of the methods and/or procedures used by the plant operators for treatment of the coke oven gas. Because of their high volatility, the exposures of workers to these toxics occurred only during coke oven operation. Apparently, the toxics are quickly dispersed and diluted in the atmosphere.

The contaminants that currently pose a major hazard to the general public include BTEX, PAHs, phenols, PCB, and deposited particulates laden with regulated metals that are found in varying quantities on the site and the surrounding areas. It might be useful to provide a brief rationale for the formation of these emissions, particularly during the coking and coke quenching stages, which were the main contributors. The available information suggests that little attention was paid to the chemical composition of the particulates, although they might be a major cause of the site contamination. In this case, the content of trace elements, particularly those which should be regulated by the environmental authorities, is crucial.

Coking

After charging the coke battery, the coal is maintained between 100 and 200°C to remove moisture. The temperature begins to increase after most of the moisture is removed. A gradual increase in temperature to about 1000°C takes several hours. Evolution of light liquids (including BTEX and phenols) begins above 350°C. The results in Table 2 obtained during the slow heating of two Cape Breton coals up to 550°C (Furimsky and others 1984) show that the yield and composition of the liquids and gases reflect coal pyrolysis occurring during the early stages of coke making. A relatively high content of H_2S in the gas should be noted. The toxics, such as H_2S, AsH_3, NH_3, and some HCN, are released during this period. The average molecular weight of the liquids increases with increasing temperature because of a gradual increase in the evolution rate of the PAHs. After a significant dehydrogenation of coal (i.e., in a semicoke region and after), most of the volatile sulfur is released as CS_2 and COS, whereas the formation of NH_3 is gradually replaced by that of HCN. Then, the type and amounts of toxics

Table 2.   Yields of pyrolysis products from Cape Breton coals

	Devco	Prince
Proximate		
Ash	2.7	14.7
Moisture	1.9	6.4
Volatiles	36.8	33.9
Fixed carbon	58.6	45.1
Yields (wt %)		
Tar + BTEX[a]	13.5 (14.2)	9.9 (12.5)
Gas	7.4 (7.8)	7.3 (9.3)
Water	5.9	10.0
Gas composition (vol. %)		
CO	3.0	3.3
CO_2	2.5	8.8
H_2	27.8	10.8
H_2S	1.8	3.5
CH_4	52.8	53.2
C_2	9.7	11.6
C_{3-6}	2.4	7.9

[a]In parentheses: yields on dry and ash free basis.

being released during the different stages of coking operation will differ.

Table 3 shows another analyses of six coals from Cape Breton. Close attention should be paid to the content of trace metals in ash, particularly that of lead, arsenic, chromium, and zinc. At the highest temperature attained during the coking process (about 1000°C), a large portion of the arsenic and lead in coal is in the vapor phase as As_2, AsN, Pb, $PbCl_2$, etc. The established trends suggest that the evaporation of these metals is improved under oxygen-deficient conditions, such as those present in coke ovens (Furimsky 2000). Upon cooling, both lead and arsenic solidify in the form of fine particles and/or are deposited on the surface of the fine particles of coke. These particles were polluting the environment because they were not completely removed from the coke oven gas. This is confirmed by results in Table 4 (RMS). Established information confirms that such particulates can be carried hundreds of kilometers from their point of origin (Querol and others 1996). It is believed that, to a certain extent, Newfoundland and Prince Edward Island (P.E.I.) were also contaminated by the plant. However, this could only be confirmed by the analysis of samples taken from these regions. It is not clear (from available information) what kind of system, if any, was used to clean the coke oven gas in the plant. For example, BTEX and phenols can still be found inside the coke oven stacks above ground level (www.muggah.org). This would suggest that a well-known carcinogen, such as benzene, which is more volatile than phenols,

Table 3.   Properties of coals from Cape Breton

	1	2	3	4	5	6
Proximate (DB) (wt %)						
Ash	11.0	24.3	28.9	2.3	8.1	4.8
Volatiles	36.8	29.7	26.7	36.0	33.5	36.0
Fixed carbon	52.2	46.0	44.3	61.7	58.4	59.2
Ultimate (DB) (wt %)						
Carbon	72.8	63.2	55.6	83.4	77.4	81.5
Hydrogen	4.8	4.1	3.8	5.2	4.8	5.1
Sulfur	3.8	1.9	2.1	1.1	2.9	2.0
Nitrogen	1.4	1.3	1.2	1.6	1.4	1.5
$Oxygen_{diff}$	6.3	5.2	5.4	6.3	5.4	5.1
Some minor and trace metals in ash (ppm)[a]						
Arsenic	804	140	101	346	70	782
Lead	764	289	284	311	359	330
Cadmium	0	0	2	6	4	9
Chromium	100	126	117	162	120	138
Zinc	432	200	243	571	542	497
Halogens (ppm)						
Chlorine	2534	804	5717	6666	4672	777
Fluorine	29	135	163	15	65	46

[a]Suit of Cape Breton coals varying in the degree of cleaning.

Table 4.   Concentration of lead in soil and vegetables

	Control area	Polluted area[a]	
		2 km	16 km
Soil	3.8	987	126
Lettuce	6.9	632	63
Potato	4.7	298	61
Cabbage	7.2	651	71

[a]Change from 2 to 16 km

was regularly emitted to the atmosphere during operation of the coke ovens.

Estimation of Liquid and Solid Emissions from Coke Making

Of particular interest is the hazardous waste resulting from plant operation, which is the cause of the contamination up until to now. It was reported that in 1975 approximately 95% of ground-level pollutants in the plant arose from coke making (RMS). It is, therefore, obvious that coke making was the main contributor during the previous and subsequent years. Certain information suggests that for a particular period, BTEX was refined on the site and sold as a final product. This market, however, dried out. The inventory of the items currently on the site indicates a temporary storage of BTEX. The amount still found on the site accounts only for a fraction of what was produced. Presumably, a portion of the BTEX evaporated and the other portion

was disposed of on the site, i.e., mostly into Muggah Creek. The heavy fraction of the by-product liquids represents tar which consists of the PAHs and phenols. The particulates laden with arsenic, lead, zinc, and other metals were the additional source of the contamination. Based on the above discussion and the published information (Chen and others 1999), these particulates may be characterized as toxic waste. In the case of the Sysco plant, the particulates were either not characterized, or if they were, the results cannot be verified. It should be noted that the potential contribution of the particulates to the contamination of the site and surrounding area has not been fully recognized, i.e., most of the focus is on contamination from the tar.

In this study, an attempt is made to estimate the amount of BTEX and tar from the very limited information that is available. It is stated that the coke production increased from 300,000 tons in 1972 to 600,000 tons in 1975, which represented 42 and 84% of the coke oven design capacity, respectively. This required about 600,000 and 1,2000,000 tons of coal, respectively. Based on the published data for Devco coal (Furimsky and others 1984), it can be estimated that the volatiles consisted of similar amounts of gases, BTEX, and tar. Then, if the increase in coke production between 1972 and 1975 was gradual, the total amount of tar and BTEX produced between 1972 and 1975 would be about 600,000 tons of tar and of BTEX. It is stressed that about 600,000 tons of tar would be produced during four years of plant operation only. This number

may be an indication of the amount of tar produced during about 90 years of operation. Because there was no market for the tar, its entire production was most likely disposed of into Muggah Creek. Information on the amount of coal used and coke produced during the lifetime of the plant would be needed to make a more accurate estimate. This simple rationale may be sufficient to indicate the extent of the hazardous waste disposal on the site. It is again emphasized that the plant operation continued from the early 1900s until 1988, suggesting that the total amount of tar and BTEX disposed could represent many millions of tons.

It is rather difficult to estimate the extent of secondary contamination by BTEX and tar. It is obvious that the clay material at the bottom and along the banks of Muggah Creek was contaminated, particularly after the tar was disposed of. The movement of the organic material towards Sydney Harbor resulted in significant contamination of harbor sediment. In the case of both Muggah Creek and Sydney Harbor, the state of the sediments and the amount of deposited sludge are unknown. This can only be determined by obtaining samples and analyzing them. As the report on material sampling reveals, contamination of the soil by BTEX and tar in the area of the plant area was established in 1997. In some cases, the contaminated soil was covered with other materials, e.g., slag from blast furnace. This suggests that in some parts of the plant, several layers of contaminated material may be found.

One source of information estimated that the average deposition of particulates in Sydney in 1977 was about 30 g/m^2/day, i.e., about 13 kg/m^2 annually (RMS). On average, about 0.5 ton/m^2 of the particulate deposit would accumulate after some 40 years of plant operation. This would result in an approx. 20-cm layer. Obviously, the thickness would increase towards the center of the plant and decrease outward. Another source indicates that in 1972, some 109 ton/day of particulates were emitted from the plant (RMS). This translates into 1,000,000 tons of the particulates deposited during 25 years of plant operation. In order to obtain a daily average deposit of 30 g/m^2/day, this amount would have to be deposited on an area of about 3.6 km^2, which approaches the total area of the Sysco plant. This suggests that the data only reflect the deposition in the plant area. It is emphasized again that this deposition on site could have changed the nontoxic nature of slag from the blast furnace and the original soil. Table 4 indicates significant contamination as far as 16 km from the plant (RMS). As expected, the soil contamination increased towards the plant. Because of the relatively high content of arsenic and other metals in the coal used for the coke production, these metals

are almost certainly present; however, they are not reported. The presence of toxic metals in agricultural produce and vegetables suggests that a thorough evaluation should be extended to include other vegetation because some constituents can become airborne and pose a hazard to the general public, particularly in a dry form. Farm animals consuming contaminated grass and other vegetation could be also affected, compromising the production of beef, milk, eggs, etc., in the area. Verification of these issues appears to be essential.

In the Sydney Tar Ponds, the toxic waste includes organics such as BTEX, tars, and phenols. The discussion above suggests that the amount of these materials exceeds the current estimate of 700,000 tons by many times. The originally nontoxic materials (soil, bottom of Muggah Creek and Sydney Harbor, blast furnace oven slag, etc.), which were subsequently contaminated with the organics, may fail toxicity tests. In such a case, these materials have to be classified as hazardous and toxic waste as well.

Because the particulates from coke making are laden with toxic metals, they may contaminate the surrounding area by admixing with the originally nontoxic solids and leaching out toxic species. Most likely, during the lifetime of the plant, several million tons of particulates were deposited on the plant and surrounding areas. This was followed by contamination of the soil, vegetation, and other originally nontoxic materials, as confirmed by the results in Table 4. Therefore, contamination of the plant and surrounding areas from particulates, which usually receives much less attention than that from the organics, deserves much more attention. The total amount of toxic waste in the Sydney area must include organics and deposited particulates, as well as the subsequently contaminated originally nontoxic materials. It is believed that the total amount of hazardous waste in the region approaches many millions of tons.

Decades of surface contamination in the Sydney area have had an adverse effect on the quality of the surface and ground waters. In this regard, few analytical data are available, although fishing in Sydney Harbor has been forbidden for several years. It is fair to assume that after several decades, toxic organic and inorganic species leached out from the contaminated soil and entered the groundwater as well. Information on hydrogeology of the site may indicate the direction of groundwater movement. This issue can only be clarified after undertaking an extensive drilling and sampling program. Potential contamination of drinking water in the Sydney area indicates the need for such a program, since the latest information suggests that contaminated water has entered the basements of house-

holds near the coke oven plant. However, without a detailed sampling and evaluation program, the extent of the water contamination may only be speculated upon.

Conclusions

Referring to the contaminated site as the Sydney Tar Ponds may be misleading because the site contamination by toxic metal-containing particulates is a more serious contributor. The lack of data on the hazardous and toxic nature of the waste on the Sysco plant site and surrounding area prevents an accurate estimate of the total amount of waste necessary for selecting appropriate cleanup methods and determining the overall cost. The rationale used in this study suggests that the amount of waste to be cleaned exceeds the reported amount (700,000 tons) by many times. It is essential that an extensive program involving an analysis of samples taken from the surface and various depths in the Sysco plant and surrounding areas be undertaken to establish an inventory of hazardous and toxic waste. Only with such a database can a reasonable conclusion on the final fate of the site be reached. This analysis may result in a decision to clean either a part of or the entire site. Given the large volumes of toxic wastes suspected at the site, the cost and logistics of the cleanup may be prohibitive and declaring either part of or the entire area as a hazardous and toxic site is not entirely unlikely. The limited information that is available suggests that accurate mapping and/or inventorying of the waste at the Sydney Sysco plant is only in the early stages.

The Sydney Tar Ponds site is the result of a lack of environmental regulations and laws. However, although some regulations were in effect during the last two decades of the plant operation, they were not adequately applied. The need for thorough environmental assessment before permits can be granted for any new industrial activity is the lesson that can be learned from the Sydney Tar Ponds case. This may require the anticipation of issues and events that are not yet regulated.

Literature Cited

Anonymous. 1994. The dictionary of substances and their effects. Royal Society of Chemistry, Cambridge, UK.

Chen, M.-L., I. F. Mao, M.-Y. Wu, J.-R. Chen, C.-K. Ho, T. J., Smith, D. Wypij, and D. C. Christiani. 1999. Assessment of coke oven emissions exposure among coking workers. *Amer Ind Hyg Assoc J,* 60:105–110.

Chung, K. H., L. C. G. Janke, R. Dureau, and E. Furimsky. 1996. Leachability of cokes from fluid coking of Athabasca bitumen. *Environ Sci Eng* 00:50.

EC. 1993. User's guide to hazardous waste classification. Environment Canada.

Furimsky, E. 1996. Spent refinery catalysts. Environment, safety and utilization. *Catal Today* 30:223–286.

Furimsky, E., L. Vancea, and R. Belanger. 1984. Effect of coal rank on structure of tars from pyrolysis of Canadian coals. *Ind Eng Chem* 23:134–140.

Furimsky, E. 2000. Characterization of trace elements emissions from coal combustion by equilibrium calculations, *Fuel Proc Technol* 63:29–39.

Gordon, J. 1997. Sydney tar ponds—it's time to clean up Canada's national shame. *Hazard Mat Manag* April/May.

Hockeny, A. G. 1970. Exposure of coke oven workers to arsenic. *Br J Ind Med* 27:56–60.

Holowaty, O., R. G. Phelps, W. DuBroff, and G. L. Landsly. 1980. Coal carbonization. Pages 436–493, in R. A. Meyers, (ed.), Coal handbook.

Lecuyer, L., S., Bicocchi, P. Ausset, and R. Lefevre. 1996. *Waste Manag Res* 14:15–22.

NCIC (National Cancer Institute of Canada). 1997. Canadian Cancer Statistics, p. 24.

Querol, X., A., Alist, A., Lopes-Sober, E. Mantilla, and F. Plana. 1996. Mineral composition of atmospheric particulates around a large coal-fired power station. *Atm Environ* 30:3557–3563.

US EPA. 1990. Federal Register, Part II, March. 40 CFR part 261.