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Field Study

An Evaluation of the Occupational Health Risks to Workers in a Hazardous Waste Incinerator

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Abstract: An Evaluation of the Occupational Health Risks to Workers in a Hazardous Waste Incinerator: Mithat BAKOĞLU, *et al*. University of Kocaeli, Department of Environmental Engineering, Kocaeli, Turkey—A study was conducted to evaluate the health impact of airborne pollutants on incinerator workers at IZAYDAS Incinerator, Turkey. Ambient air samples were taken from two sampling points in the incinerator area and analyzed for particulate matter, heavy metals, volatile and semi-volatile organic compounds (VOCs and SVOCs) and dioxins. The places where the maximum exposure was expected to occur were selected in determining the sampling points. The first point was placed in the front area of the rotary kiln, between the areas of barrel feeding, aqueous and liquid waste storage and solid waste feeding, and the second one was near the fly ash transfer line from the ash silo. Results were evaluated based on the regulations related to occupational health. Benzene, dibromochloropropane (DBCP) and hexachlorobutadiene (HCBD) concentrations in the ambient air of the plant were measured at levels higher than the occupational exposure limits. Dioxin concentrations were measured as 0.050 and 0.075 pg TEQ.m^{-3}, corresponding to a daily intake between 0.007 and 0.01 pg TEQ. kg body $weight^{-1}.day^{-1}$. An assessment of dioxin congener and homologue profiles suggested that gaseous fractions of dioxin congeners are higher in front of the rotary kiln, while most of them are in particle-bound phases near the ash conveyor. Finally, the necessity of further studies including occupational health and medical surveillance assessments on the health effects of the pollutants for the workers and the general population in such an industrialized area was emphasized.
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Waste incineration technology has been used for destroying contaminated hospital waste, reducing municipal waste volume, substantially cutting the amount of hazardous wastes (chemical and biological) and producing energy for a long time in the world. Nevertheless, it is rather a new topic for Turkey. The first, and for the present, the only incinerator in Turkey is Izmit hazardous and clinical waste incinerator (IZAYDAS), which was built in Izmit, the most industrialized area in Turkey, and started to operate in December 1997. At the time, some strict legislative controls had been introduced by the European Commission due to the environmental risks caused by the incinerators and the public concern over the emission of pollutants such as particles, heavy metals, acid gases, and especially dioxins.

Although incineration is an effective way of treating solid wastes, the potential public health effects associated with stack emissions have caused serious concern in the local population. Therefore, quantitative risk assessment tools have been used for almost a decade to evaluate the health risks of the stack emissions from the incinerators. There are many frameworks[1–3] and publications[4, 5] related to the risk assessment of waste incinerators, paying special attention to dioxins. But the existing frameworks used to assess human exposure and the health effects of incinerators have been generally focused on local populations, but excluded workers and larger regional populations. And assessing the health impact involving on-site workers requires the consideration of source-to-dose relationships that are not necessarily proportional to the mass of toxic stack emissions released during ideal conditions. This is because during start-up and transient events, ideal conditions are unattainable and pollution emissions can increase significantly. Equipment failures can also significantly increase pollutant emissions.

This study was conducted to evaluate the health impact of airborne pollutants on incinerator workers at

IZAYDAS. Ambient air samples were taken at two sampling points in the incinerator area and analyzed for particulate matter, heavy metals, VOCs, SVOCs and dioxins. Results were evaluated based to the regulations related to occupational health.

Methods

1. The Plant

Detailed information on the IZAYDAS Incinerator was given by Bakoglu *et al.*[6] It has a two-stage combustion system consisting of a rotary kiln and a vertical shaft. The capacity of the plant is 35,000 t.y^{-1} and is equipped with an electrostatic precipitator (EP), a Venturi scrubber, a lime-scrubber and an activated carbon (AC) unit. The EP and Venturi scrubber remove particulate matter (coarse and fine), and the lime scrubber is used for the removal of acid gases and SO_2 from the flue gas stream. An additional AC unit (passive-bed type) was installed at the plant in 2000, for the removal of dioxins due to the increasing public concern over these chemicals.

Industrial and clinical wastes (in liquid and solid forms) are combusted in the incinerator. Solid wastes that are fed to the rotary kiln by the bunker include various industrial wastes coming from different industries and clinical wastes in tablet or powdered forms and their plastic packages. Most of the liquid wastes of industrial origin are also fed to the rotary kiln in barrels. Only some waste oils with high calorific value are directly fed to the vertical furnace to serve as auxiliary fuel.

All the weighing, storing and feeding facilities are in closed systems to avoid any gas/vapor leakage to the ambient atmosphere. Some of the solid wastes are carried in the barrels and emptied into the bunker area. Other solid wastes that are transported by dump truck are unloaded by opening the dumper. The bunker area is a closed room with a door and is ventilated continuously. Most of the liquid wastes are brought in barrels and transferred to the feeding tanks in a closed system. For the hazardous liquid wastes, on the other hand, a container with a 5,000-liter capacity is sent to the facility where they are produced, and the wastes are filled in situ to be transferred to the incinerator. Medical wastes, which are also transported in barrels, are taken by forklifts to the feed-inlet for automatic feeding.

Handling and removal of solid residues of the plant are conducted in closed systems. The slag produced in the rotary kiln is taken to an ash quench chamber to mix with water for 10 min and then it is transferred to a landfill site by a bunker. Fly ashes containing the particles removed by electrofiltration of flue gas and the particles accumulated in the boiler are spilled by a hammering system and then they are carried to the ash silo by closed conveyor bands. Finally they are transferred by a heated conveyor to the equalization tank of the wastewater treatment plant to be used as a coagulant.

It could be seen that workers' contact with airborne pollutants (gases and particles) in the working environment is at a minimum during daily operation of the plant. Periodic maintenance, on the other hand, is generally conducted once a year. But, manual cleaning of the inside of boiler and ESP by workers (which would cause a serious health risk due to the fly ash) has not been needed until now.

2. Sampling Points

Although contact between the workers and airborne

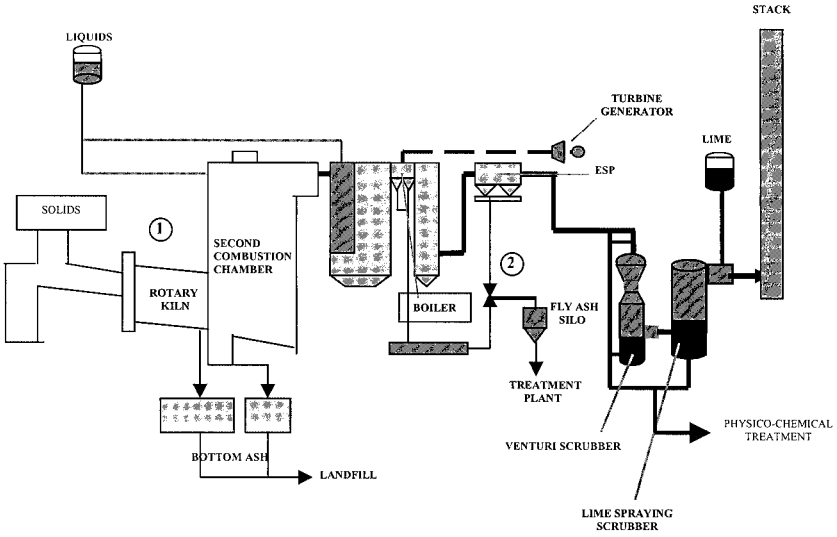


Fig. 1. Flow scheme of the IZAYDAS Incinerator and the locations of sampling points.

pollutants is minimized at the plant, there have been some fugitive emissions (from the connection points, etc.) causing complaints by workers. Therefore, places where maximum exposure was expected to occur were selected in determining the sampling points (SP). For this, two critical points were selected (see Fig. 1): The first point was placed in the front area of the rotary kiln, between the areas of barrel feeding, aqueous and liquid waste storage and solid waste feeding. This point represents the place where the fugitive pollutants from the front part of the rotary kiln (such as particles, combustion gases and volatile organic compounds) are concentrated. These leakages are mainly caused by the overloading of solid wastes from the bunker and/or in barrels to the rotary kiln, creating a pressure difference in the kiln. Miscellaneous odor leakages from the liquid storage areas and fugitive vapors from the ash quenching chamber (due to the insufficient vacuum) also come to this place.

The second sampling point was near the transfer line of the fly ash from boiler and ESP to the ash silo. Although these ashes (a mixture of the fly ash retained in the boiler and ESP) are transferred by a closed screwed-conveyor system, and some leakages could take place, especially from the connection points. Therefore, a second sampling point was selected here by considering the possible health effects resulted from the inhalation of the fly ash containing pollutants (such as heavy metals, VOCs, SVOCs and dioxins etc.). These two points were assessed as the most risky places in the incinerator area from the health point of view, with regard to chronic exposure to airborne pollutants. Ambient air samples were taken from these points and analyzed for particulate matter, heavy metals, VOCs, SVOCs and dioxins. Since the sampling points were outdoors, sampling periods were chosen to be as calm as possible to minimize the effects of atmospheric conditions (wind, precipitation, etc.), especially in the one-day samplings for particulate matter, heavy metals, VOCs and semi-VOCs. Samplings were performed in the open and in dry weather in May 2003.

3. Sampling and Analyses

Ambient air samples were taken in different volumes for analysis of the pollutants. Air samples of about 1 m^3 were taken in sampling periods between 16–24 h for particulate matter, heavy metals, VOCs and SVOCs. Samples were taken by a sampling train including a stainless steel probe, a condenser, silica gel and a gas-sampler (ZAMBELLI 6000 PLUS). Particulate matter was retained by a glass fiber filter (with a 1 μm sieve) and then measured gravimetrically. For heavy metals, air samples were passed through three impinger solutions of 100 m/ 0.1 M HNO_3 (submerged in an ice bath). Then the samples were analyzed directly by ICP/AES according to the DIN 38406-E22 Method. VOCs and SVOCs were retained by two successive activated carbon columns and analyzed by GC/MSD (HP 6890 GC 5973 N MSD) after 24-h acetone extraction according to the EPA 8260 Method. For dioxins, air samples of about 1,000 m^3 were taken in 6-day sampling periods. They were retained by a system including a glass fiber filter for particle collection and a polyurethane foam (PUF) cartridge (according to the EPA TO-9A Method) and analyzed by HRGC/HRMS after 48-h toluene extraction in a certified laboratory in Germany (*Dr. Wessling Laboratories, Germany*) according to the EPA 1613 Method. Toxic equivalents as 2,3,7,8-TCDD (TEQ) were calculated by using the international toxicity equivalency factors (I-TEF) of the World Health Organization[7].

Results

1. Particulate Matter and Heavy Metals

Particulate matter in the indoor air in incinerators mainly originates in the fugitive emissions from the ash transfer lines. The leakages from the flue gas movement through the pollution control devices and stack, and the particulate emissions to the atmosphere from the stack may have an effect, too, but the extent of it could be regarded as negligible. Most of the particles present in ambient air are composed of finer fractions, since the fine particles can be easily scattered by disturbance and remain suspended in the air for a long time, whereas coarse particles cannot. The size of the particles suspended in the breathing zone may be 100 μm and less[8]. On the other hand, previous studies showed that most of the pollutants in the flue gas tend to be concentrated in finer particulate matter fractions. Especially organic compounds that are volatile at flue gas temperatures are believed to be enriched in finer particles (by adsorbing on their surfaces) due to their high surface area/volume ratios[5]. Furthermore, there are many studies showing that heavy metals are also concentrated in finer fractions[9–11]. A study on the metal partitioning in solid residues of the IZAYDAS Incinerator agreed with these studies, showing that most heavy metals entraining in flue gas are retained in finer particle fractions[6]. The concentrations of particulate matter and heavy metals measured in ambient air in the incinerator are given in Table 1.

Results showed that the measured concentrations of particulate matter and metals were below the national and international occupational exposure limits. Although the particulate matter concentration in the front of the ash conveyor was very high, heavy metal concentrations did not correspond to it. Heavy metal contents of flying ash in the IZAYDAS were studied in detail by Bakoglu *et al.*[6] They showed a rank of Zn>Cu>Pb>Ni>Mn>Co in fly ash (other metals were not included). Comparing this with the rank at SP 2 shows that manganese and nickel have considerably high ambient air concentrations with respect to their flying ash content, while the opposite is true for lead. This statement is also true for the

Table 1. The concentrations of particulate matter and heavy metals at sampling points

Parameter	Concentrations ($\mu g.m^{-3}$) Sampling Point No: 1	Sampling Point No: 2	Exposure limit values[a]
Particulate Matter	0.5	36	1500[b]
Heavy Metals			
Arsenic	<0.003	<0.003	10
Mercury	0.511	0.019	10[c]
Cadmium	<0.001	<0.001	100
Manganese	0.016	0.125	1000[d]
Copper	0.122	0.118	100
Nickel	0.043	0.098	7[e]
Lead	0.274	0.075	50
Zinc	3.827	2.734	1000[f]
Cobalt	0.0009	0.0004	100

[a]Occupational Safety and Health Administration's permissible exposure limits (PEL) expressed as a time-weighted average; the concentration of a substance to which most workers can be exposed without any adverse effect averaged over a normal 8-h workday or a 40-h workweek. [b]Turkish national limit. [c]For organoalchyl compounds. [d]National Institute of Occupational Safety and Health's (NIOSH) recommended exposure limit (REL); for an 8- or 10-h time-weighted-average exposure. [e]For nickel carbonyls. [f]For $ZnCl_2$

comparison between the results for points 1 and 2. In general, the most volatile metals (Hg and Pb) showed lower concentrations in front of the ash conveyor than in front of the rotary kiln, whereas other metals with less volatility had similar concentrations to (Cu, Zn and Co), or higher concentrations (e.g. Mn and Ni) at sampling point 2, compared to the values at SP 1. Although the low metal concentrations in the presence of high particulate matter suggest that heavy metals in the ambient air are in gaseous forms rather than in particle-bound forms at sampling point 2, nucleation/condensation processes during flue gas cooling could play a significant role too. Wichmann *et al.*[10] states that both heterogeneous condensation and reaction processes of metal species taking place on the surface of particles result in an enrichment of metals in the fine particles, whereas homogeneous condensation (nucleation) enables the formation of new particles <1 μm from the gas phase. The contradiction between the particulate matter and heavy metal concentrations could be attributed to gaseous metallic compounds and enrichment of the metals in ultra fine particles that could not be retained by the filter.

Heavy metal concentrations in front of the rotary kiln result mainly from the leakages from the rotary kiln during waste feeding. Since the particulate matter concentration was very low here, it could be said that gaseous metallic compounds are dominant. This could be explained by the rotary kiln temperatures (between 950 and 1,050°C), which are high enough to volatilize the most of the metals. Zinc showed the highest concentrations possibly due to its presence in larger quantities in feed waste. On the other hand, the mercury concentration at SP 1 is significant, because wastes with a measurable Hg content are not accepted at the plant for combustion, meaning that Hg in the waste should be in only trace quantities. But Hg showed the second highest concentration at SP 1. Therefore, special attention should be paid to the Hg content in the wastes, considering its possible health effects.

2. VOCs and SVOCs

Organic pollutants in the ambient air of the incinerator originate mainly in the bunker and barrel storage areas due to the volatilization and/or degradation of organic compounds in the solid/liquid wastes and they are diffused into the atmosphere from containers with insufficient tightness as they have high vapor pressures. VOCs and SVOCs measured in IZAYDAS Incinerator are shown in Table 2.

The concentrations of organic compounds measured at the sampling points were generally below the national and international occupational exposure limits. The exceptions were benzene, hexachlorobutadiene (HCBD) and 1,2-dibromo-3- chloropropane (DBCP). Benzene is a category 1 IARC carcinogen (known as human carcinogen), whose presence in ambient air results from the emissions from burning coal and oil, gasoline service stations, and motor vehicle exhaust, etc. Its permissible exposure limit (PEL) value accepted by the Occupational Safety and Health Administration (OSHA) is 3.2 $mg.m^{-3}$

Table 2. The concentrations of VOCs and SVOCs at sampling points

Compound	Concentrations (ppb) Sampling Point No: 1	Sampling Point No: 2	Exposure limit values[a]
Benzene	25.46	1331.29	1000
Toluene	7.93	51.33	200×10^3
Tetrachloroethylene	5.24	8.39	100×10^3
Dibromochloromethane	1.34	2.08	–
1,2-Dibromoethane	0.01	0.01	20×10^3
Chlorobenzene	6.28	9.91	75×10^3
Ethyl benzene	10.69	15.28	100×10^3
1,1,1,2-Tetrachloroethane	2.49	3.33	–
m-Xylene	4.63	6.52	100×10^3
p-Xylene	<0.02	35.94	100×10^3
o-Xylene	3.04	<0.02	100×10^3
Styrene	2.98	5.7	100×10^3
Isopropyl Benzene	9.11	0.02	50×10^3
1,1,2,2-Tetrachloroethane	3.93	6.61	5000
Bromobenzene	2.23	3.58	–
n-Propyl Benzene	4.19	5.36	–
1,3,5-Trimethylbenzene	4.28	<0.02	25×10^3
1,3-Dichlorobenzene	5.36	<0.02	–
1,4-Dichlorobenzene	1.46	1.83	75×10^3
1,2-Dichlorobenzene	4.56	14.86	50×10^3
1,2-Dibromo-3- Chloropropane	*2.63*	*5.09*	*1*
1,2,4-Trichlorobenzene	3.72	7.75	5000[b]
Hexachlorbutadiene	*97.83*	*<0.01*	*20[b]*
Naphthalene	7.21	1.18	10×10^3
1,2,3-Trichlorobenzene	3.91	8.19	–

[a]Occupational Safety and Health Administration's permissible exposure limits (PEL) expressed as a time-weighted average; the concentration of a substance to which most workers can be exposed without any adverse effect averaged over a normal 8-h workday or a 40-h workweek. [b]NIOSH REL.

(as a time-weighted average; the concentration of a substance to which most workers can be exposed without any adverse effect averaged over a normal 8-h workday or a 40-h workweek.)[12], while the National Institute of Occupational Safety and Health (NIOSH) recommends one tenth of the amount[13]. The benzene concentration in front of the ash conveyor exceeded these limits, however, and this remains in a range which is typical for urban ambient air. Many previous studies showed similar benzene concentrations for different urban areas in the world[14–17].

Dibromochloropropane (DBCP), on the other hand, is a brominated organochlorine nematocide, (pesticide used to control worms) that was widely used in agriculture due to its effectiveness on perennial crops without damaging the plants (especially for some vegetables and flowers) in the world from the mid-1950s until the 1980s, but the discovery of adverse reproductive effects in humans led to the United States imposing a partial ban in 1977 and a total ban in 1987. At present, although it is used as an intermediate in the synthesis of organic chemicals including flame-retardants, essentially all of its present use is still as a soil fumigant. It is classified as a carcinogen by OSHA and IARC (2B: possibly carcinogenic to humans). Its mutagenicity, carcinogenicity and reproductive effects (especially effects on human testicular function) were studied by many researchers[18–22]. DBCP has been shown unequivocally to produce testicular toxicity and sterility in exposed male workers in a dose-response relationship[18].

For inhalation, OSHA requires that employers ensure that no employee is exposed to an airborne concentration of DBCP in excess of 1 part per billion (ppb) (0.01 $mg.m^{-3}$) of air as an 8 hour time-weighted average (TWA). In IZAYDAS, DBCP concentrations at both sampling points exceeded this value (about 2.5 and 5 ppb at the SPs 1 and 2, respectively). Although the use of DBCP has been restricted since the 1980s, it has not been included in Turkish occupational health regulations yet. Considering

its possible health effects on humans (especially on workers), this should be taken into account in future applications.

Finally hexachlorobutadiene (HCBD) was measured at a high concentration in the front of the rotary kiln. It is found predominantly as a by-product formed during the manufacture of chlorinated solvents and related products. It is also used directly as a solvent, heat transfer liquid, hydraulic fluid and lubricant and as a chemical intermediate in the manufacture of rubber compounds, chlorofluorocarbons and lubricants. It is also used as a fumigant in some countries[23]. Although there are limited data on its effects on humans, its adverse effects including nephrotoxicity in animals have been shown by previous studies[24, 25]. Its toxicological profile and health risks following environmental exposure were also assessed in some reports[26–28]. Its recommended exposure limit (NIOSH) is 0.24 $mg.m^{-3}$. An ambient air HCBD concentration of about 1 $mg.m^{-3}$ (measured near the rotary kiln and storage areas) could result from both the volatilization of such compounds during the storage of the wastes of the tyre industry and the fugitive emissions from the rotary kiln during the incineration of these wastes. Since the wastes of the tyre industry have been incinerated at IZAYDAS in large quantities, HCBD and similar pollutants originating in these wastes should be followed up and assessed periodically by exposure and medical surveillance studies with regard to occupational health. Moreover, as three large tyre factories have been in operation since the 1970s in Izmit (and located very close to each other), health risk assessments related to such chemicals should be conducted also for the people living in Izmit.

A comparison of the concentrations of organic pollutants at SPs 1 and 2 shows that the concentrations in front of the ash conveyor are generally higher than those in front of the rotary kiln. The difference is more obvious for the most volatile compounds, i.e., benzene and toluene. This could be attributed to the adsorption of organic pollutants on the surfaces of particles during the flue gas cooling. Contaminants with relatively high vapor pressures (at stack gas temperatures) are condensed onto the surface of particulate matter emitted from the stack[5]. These compounds are generally enriched in finer particles (due to their high surface area/volume ratios), which may remain suspended in the air and behave like gaseous pollutants. Therefore, leakages from the ash transfer lines may increase their concentrations, as in the case of particles. On the other hand, the pollutants with higher concentration at SP 1 (such as HCBD) should be related to the composition of wastes that are stored or incinerated.

3. Dioxins

"Dioxins" is the general term for chemicals including polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and coplanar polychlorinated biphenyls (co-PCBs), which are highly toxic. In the study seventeen 2,3,7,8-substituted PCDD and PCDF congeners with dioxin-like toxicity were analyzed. Since the term "dioxin" came into public concern by the time IZAYDAS started to operate in 1997, several measurements of PCDD/F emissions were made in flue gas during the trial burns conducted between 1997 and 2000. Detailed information on these PCDD/F measurements in flue gas including congener and homologue profiles was given in Bakoglu *et al.*[29] PCDD/F concentrations in ambient air of IZAYDAS are

Table 3. PCDD/F concentrations at sampling points

Compound	Concentrations ($pg.m^{-3}$)	
	Sampling Point No: 1	Sampling Point No: 2
Congeners		
2,3,7,8-TCDD	0.0028	0.002
1,2,3,7,8-PeCDD	0.0035	0.0076
1,2,3,4,7,8-HxCDD	0.0072	0.007
1,2,3,6,7,8-HxCDD	0.0121	0.0121
1,2,3,7,8,9-HxCDD	0.0122	0.0145
1,2,3,4,6,7,8-HpCDD	0.1223	0.131
OCDD	0.2921	0.3195
2,3,7,8-TCDF	0.0345	0.0251
1,2,3,7,8-PeCDF	0.0222	0.0289
2,3,4,7,8-PeCDF	0.0451	0.0575
1,2,3,4,7,8-HxCDF	0.0376	0.0816
1,2,3,6,7,8-HxCDF	0.032	0.0956
2,3,4,6,7,8-HxCDF	0.0387	0.0846
1,2,3,7,8,9-HxCDF	0.0035	0.0054
1,2,3,4,6,7,8-HpCDF	0.1774	0.439
1,2,3,4,7,8,9-HpCDF	0.0278	0.0418
OCDF	0.1975	0.3283
TEQ	**0.05**	**0.075**
Homologues		
TCDD	0.0841	0.0358
PeCDD	0.0743	0.0741
HxCDD	0.1683	0.1959
HpCDD	0.2193	0.2508
OCDD	0.2921	0.3195
TCDF	0.6379	0.3687
PeCDF	0.3514	0.6466
HxCDF	0.3462	0.7187
HpCDF	0.2678	0.5815
OCDF	0.1975	0.3283
PCDD	0.8381	0.8761
PCDF	1.8008	2.6438
PCDD/F	2.6389	3.5199

summarized in Table 3.

Dioxins are well-known human carcinogens, included in IARC Group 1 carcinogens. Tolerable daily intake (TDI) was determined as 1–4 pg TEQ. kg body weight^{-1}.d^{-1} for dioxins by the World Health Organization (WHO). Assuming that inhalation is the only exposure pathway for workers, and taking the average body weight and breath volume (in 8 h) of a worker as 70 kg and 10 m^3, the TDI value could be converted to an occupational exposure limit of 7–28 pg TEQ.m^{-3}. In IZAYDAS, dioxin concentrations were measured as 0.050 and 0.075 pg TEQ.m^{-3}, which are about 1/100 of the limit value. These values are low compared to the dioxin exposure concentrations of Kumagai *et al.*[8] (in the range 0.5–7.2 pg TEQ.m^{-3}, average 2.0 pg TEQ.m^{-3}), estimated by the total dust concentrations and dioxin concentrations in dust in daily operation. Converting the exposure concentrations to daily intake values gives 0.007–0.01 pg TEQ. kg body weight^{-1}.d^{-1}, but other exposure pathways, especially ingestion of foods, should also be taken into account. At present, there are no data on the dioxin concentrations in various commercial foods in Turkey.

The evaluation of congener and homologue profiles shows that congener profiles at both points are similar, but more volatile congeners (2,3,7,8-TCDD and 2,3,7,8-TCDF) showed higher concentrations at SP 1. This is more obvious for TCDD and TCDF in homologue profiles. Moreover, there is a clear decrease in the concentration of furan homologues at SP 1 as the chlorination level increases. This could be attributed to differences in temperatures and particulate matter concentrations between the sampling points. Since SP 1 is close to the rotary kiln, temperatures at that point are generally 5–10°C higher than those at SP2. Particles in the ambient air, on the other hand, provide an area for the adsorption of these chemicals. Therefore, gas/particle partitioning of the congeners is a function of the surface area of atmospheric particles and sub-cooled liquid vapor pressure of the congeners at the ambient air, which is dependent on the ambient air temperature. Most of the PCDD/Fs at SP 2 could be assumed to be particle-bound. The patterns of PCDD/F congener and homologue profiles through the air pollution control equipment in IZAYDAS were studied by Karademir *et al.*[30] An obvious similarity between the congener and homologue profiles in SP 2 and those in the flue gas entering ESP supports this assumption.

Discussion

The findings of this study showed that concentrations of some organic chemicals in the ambient air of IZAYDAS Incinerator are higher than the occupational health limits. Furthermore, since the workers are exposed to a mixture of the chemicals studied, their effects could be assumed as additive. This implies the necessity of future studies including occupational health assessments and medical surveillance in the plant. Additionally, exposure to these pollutants in periodic maintenance should be taken into account also. Some studies have reported that the concentrations of the pollutants in ambient air increase more than hundred times during the cleaning of the inside of the equipment (especially dry particle removal systems such as the bag filter and ESP, etc.)[8, 31]. Although manual cleaning of the inside of the boiler and ESP by workers (which would cause a serious health risk due to the flying ash) has not been needed up to now, the maintenance of other equipment could also cause the pollutant exposure, which are high enough not to be neglected.

Because the incinerator incinerates various wastes including medical and industrial wastes, ambient pollutant concentrations must vary according to the kind of incinerated waste. Furthermore, as the sampling points are in the open air, they are open to atmospheric effects such as wind, temperature and precipitation, etc., which are very unstable and atmospheric conditions have a direct effect on the ambient air in the plant. The samplings were made in May, 2003 with high temperatures (between 30 and 40°C in daytime) and the sampling periods were chosen to be as calm (and dry) as possible, especially in the measurements of heavy metals and organic compounds in one-day periods, so that ambient pollutant concentrations could be measured and discussed in relation to the kinds of wastes. In fact, general weather conditions in Kocaeli are somewhat different (on an hourly basis, the frequencies of windy and rainy hours were about 0.70 and 0.42, respectively in 2001–2002 and total precipitation is about 0.8 m per year)[32]. Therefore, taking into account the small sample size and the variability of the wastes and atmospheric conditions, the measured concentrations could be assumed to have limited reproducibility and representativity, but on the other hand, they may represent the worst conditions possible to occur in the plant. Since the repetition frequency of the results is expected to be low for longer periods, comparison of them with short term exposure limits (STEL - a 15-min time-weighted average exposure which should not be exceeded at any time during a workday) or ceiling limits (the concentration of a substance that should not be exceeded at any time) could be more appropriate than with permissible exposure limits (PEL - as a time-weighted average; the concentration of a substance to which most workers can be exposed without adverse effects averaged over a normal 8-h workday or a 40-h workweek). Although STELs or ceiling limits are not determined for many organics and their ratios to PEL values change from chemical to chemical, STEL or ceiling limits are generally 2–5 times higher than the PELs for organic compounds. Taking into account that DBCP and HCBD concentrations in the

plant were 2.5–5 times higher than the corresponding PELs, and if we assume that the average PEL/STEL ratios are valid for these chemicals too, it could be concluded that these concentrations were about the same as or higher than the STELs also. Additionally, further studies will be necessary on the sources of these chemicals, i.e., the wastes, and in the places where such wastes are produced, because the workers working in the industries where these wastes are used or produced could be exposed to these chemicals for much longer times than the incinerator workers.

Finally, the health risk assessments and medical studies should be concerned for the general population in Izmit, since Izmit is the most industrialized area of Turkey. It should be noted that there are many other potential sources of environmental pollutants in Izmit, among them being two very busy traffic arteries, three tyre industries, an automobile industry, pulp and paper industry, petrochemical industry and the largest petroleum refinery (TUPRAS) in Turkey. But no information is yet available on the health risks from pollutants emitted from these sources. Therefore, besides the occupational health assessments, medical surveillance studies to be conducted in Izmit area will clarify the effects of the pollutants (which have been continuously emitted since the 1970s) on human health.

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