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SHORT COMMUNICATIONS

Air Pollution and Heavy Metal Concentration in Colostrum and Meconium in Two Different Districts of an Industrial City: A Preliminary Report

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ABSTRACT

Objective: **Environmental pollution has become a global issue affecting the public health. The purpose of this study was to measure the particle mass (PM_{10}) and heavy metal concentrations in the air of industrial and non-industrial districts in an industrial city and to determine if heavy metals are present in the colostrum of mothers and meconium of newborns.**

Material and Method: **PM_{10} presence and concentration per unit volume were determined in air samples using the Equal Pay Act-29 technique. The presence of heavy metals in PM_{10} and their amounts per unit volume were determined using Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) and cold vapor Atomic Absorption Spectroscopy. The colostrum and meconium samples were analyzed using ICP-MS and Inductively Coupled Plasma Optical-Emission Spectroscopy.**

Results: **The mean PM_{10} levels in both districts were higher than World Health Organization limit values. The mean heavy metal concentrations of Al, As, Cd, Cu, Fe, Hg, Pb and Zn in colostrum and meconium were all higher in samples from the industrial district than the non-industrial district.**

Conclusions: **These findings reveal that more effective measures against industrial pollution have to be taken in this region without delay. In order to safeguard public health, immediate measures should be taken to reduce air pollution. Further research should be carried out to monitor the effectiveness of the air pollution reduction measures.**

KEY WORDS

air pollution, heavy metal, colostrum, meconium, newborn, pregnant, industry, Turkey

INTRODUCTION

Environmental pollution has become a global issue affecting public health (Järup, 2003). Various epidemiologic studies have shown the influence of pollution on public health (WHO, 1993). The main two reasons for environmental pollution are industrialization and urbanization. Industrial chemical pollutants have been shown to affect both mortality rates and mortality patterns, resulting in new illnesses over the last few decades (WHO, 2006).

Over the last two decades, epidemiological studies have revealed that particle mass (PM_{10}) in air have adverse effects on human health (Dockery, Pope, 1994). For example, correlations have been shown between PM_{10} pollution and postneonatal mortality (Conceição, Miraglia, Kishi, Saldiva, Singer, 2001; Woodruff, Grubl, Schoendorf, 1997; Woodruff, Perker, Schoendorf, 2006), low birth weight (Bell, Ebisu, Belanger, 2007; Chen, Yang, Jennison, Goodrich, Omaye, 2002; Dugandzic, Dodds, Stieb, Smith-Doia2006; Gouveia, Bremner, Novaes, 2004; Salam, Millstein, Li, Lurmann, Margolis, Gilliland 2005), and premature births (Hansen, Neller, Williams, Simpson, 2006; Jiang, Zhang, Song, Chen, Chen, Zhao, Kan, 2007; Leem, Kaplan, Shim, Pohl, Gotway, Bullard, Rogers, Smith, Tylenda, 2006; Ritz, Yu, Chapa, Fruin, 2000; Sagiv, Mendola, Loomis, Herring, Neas, Savitz, Poole, 2005).

Heavy metals negatively impact human health in a number of ways. For example, Pb exposure can cause irreversible neurological damage in humans, especially in children (Needleman, Gatsonis, 1990). Experimental studies have also shown that chronic exposure to low doses of arsenic (As) induces fetal-growth retardation, miscarriage, stillbirth, premature birth, and neonatal death (Ahmad, Sayed, Barua, Khan, Faruquee, Jalil, Hadi, Talukder, 2001; Hopenhayn-Rich, Browning, Hertz-Picciotto, Ferreccio, Peralta, Gibb, 2000; Milton, Smith, Rahman, Hasan, Kulsum, Dear, Rakibuddin, Ali, 2005; Von Ehrenstein, Guha-Mazumder, Hira-Smith, Ghosh, Yuan, Windham, Ghosh, Hague, Lahiri, Kalman, Das, Smith, 2006; Wang, Holladay, Wolf, Ahmed, Robertson, 2006), birth defects (Kwok, Kaufmann, Jakariya, 2006), fetal loss (Hopenhayn-Rich *et al*., 2000; Rahman *et al*., 2007), and influence on verbal abilities and long-term memory (Calderón, Navarro, Jimenez-Capdeville, Santos-Diaz, Golden, Rodriguez-Leyva, Borja-Aburto, Díaz-Barriga, 2001). Cadmium (Cd) exposure in the womb are linked to deficiencies in motor and perceptual skills, as well as mental retardation during childhood (Schoeters, Den Hond, Zuurbier, Naginiene, Van Den Hazel, Stilianakis, Ronchetti, Koppe, 2006; ATSDR, 1999; Counter, Buchanan, 2004; Goldman, Shannon, 2001), while exposure of mothers to mercury (Hg) results in infant neurological damage, such as severe mental retardation, cerebral palsy, delay in walking and speech (Ronchetti, Zuurbier, Jesenak, Koppe, Ahmed, Ceccatelli, Villa, 2006). At high concentrations, As, Cd, Hg, Aluminum (Al), neurotoxic metals obstruct prenatal and postnatal brain development (Nayak, 2002). The exposure to high levels of zinc (Zn) during pregnancy has toxic effects on the fetus (Chang, Mann, Gauteri, 1977; Cox, Schlicker, Chu, 1969). The high doses of Cu (> 80 mg/kg daily)

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also have toxic effects on fetuses and result in malformations (WHO, 1998). Excess Fe causes deterioration in normal endocrine functions as it accumulates in the anterior pituitary gland. Thus, growth retardation and sexual maturation disorder follow (Vichinsky, 2009).

In humans, the first potential exposure to heavy metals occurs during gestation. After birth, heavy metal exposure occurs primarily through breast milk. Human breast milk is typically the sole food source for infants for the first four to five months of life. Like other body fluids, breast milk normally contains trace levels of most metals and other elements. Some of these elements are essential to life, while others are toxic at higher concentrations (Jensen, 1991). As, Pb, Hg, Cd, Zn, Cu and Al are listed as toxic metals on the Priority List of Hazardous Substances announced by the Agency for Toxic Substances and Disease Regastry (ATSDR, 2007). Many chemicals can be transferred to the breast milk of a lactating mother from body stores and circulating blood. Heavy metals exposure may also occur through panting air and drinking water (Ursinyova, Masanova, 2005). In risk assessments, it has to be borne in mind that the absorption of heavy metals in infants is generally higher when they are on a milk diet, probably due to heavy metal binding to milk proteins that are readily absorbed by infants (Jensen, 1991; Jugo, 1977).

A few Turkish studies have previously determined the concentrations of heavy metals in colostrum and meconium of newborns (Ermis, Cizmecioglu, Bertman, Guray, 1994; Turan, Saygi, Kilic, Acar, 2001; Turker, Ergen, Karakoc, Arisoy, Barutcu, 2006; Yalcin, Orün, Mutlu, Madendag, Sinici, Dursun, Ozkara, Ustünyurt, Kutluk, Yurdakok 2010; Orün, Yalcin, Aykut, Orhan, Morgil, Yurdakok, Uzun, 2011). The purpose of this study was to measure PM10 and heavy metal (Al, As, Cd, Cu, Fe, Hg, Pb, Zn) air concentrations in air samples from two districts of an industrialized city. The study also aimed to investigate whether exposure to industrial pollution affected the concentration of heavy metals (Al, As, Cd, Cu, Fe, Hg, Pb, Zn) in the colostrum of mothers residing in these districts who were not exposed to heavy metals occupationally, and in the meconium of their newborns.

MATERIAL AND METHOD

Study Population and Recruitment

The study consisted of four stages: 1) determination of PM_{10} and heavy metals in air samples; 2) pregnancy follow-up; 3) determination of heavy metals in colostrum and newborn meconium samples and 4) monitoring infant growth and development. The fourth stage of the study is currently ongoing, so is not covered in this paper.

Kocaeli, the site of this study, is an industrial city located in the Marmara Region of Turkey 70 km from Istanbul. This city covers a surface area of 3.505 km^2 and has a population of 1.522.408 people. It is the second largest industrial city in Turkey and currently has a 13% share of the Turkish manufacturing industry. In 2009, in Turkey, 2.82% of consumer goods, 22.03% of intermediate goods and 10.23% of investment goods were manufactured in Kocaeli. The industrial enterprises are mainly concentrated in three of the city's 12 districts (Gebze, Izmit and Körfez). One study district was in an industrial district (Dilovasi) while the second study district was in a non-industrial area (Kandira) (KCI, 2011).

In this study, samples were collected in the industrial district of Dilovasi, which has the highest concentration of industries and the highest prevalence of health problems, and the non-industrial district of Kandira. The Dilovasi has nine seaports through which the D-100 and TEM highways pass. Since the 1980s, it has experienced significant population growth due to free-trade arrangements and the increase of industrialization resulting from private sector investments. The Dilovasi Organized Industrial Zone (DOIZ) is located in the centre of the district and 174 companies are registered within the zone. Thirteen percent of the firms in the area operate within the metal and metal products industry sector. A number of these plants process scrap metal. Eleven percent of the companies in the DOIZ are heavily involved in the paint and chemical industry sectors (Hamzaoglu, Etiler, Yavuz, Caglayan, 2011). The Kandira is located in the northern part of Kocaeli, on the Black Sea coast. Crop and livestock farming, fishery and tourism are the major industries in the district (KDA, 2011).

Air Sample Analysis

Airborne dust sampling and heavy metal analysis were carried out by the Environment Institute of the Scientific and Technological Research Council of Turkey Marmara Research Center (TÜBİTAK-MAM). The sampling locations were determined by the researchers and TÜBİTAK-MAM Environment Institute officials and remained unchanged throughout the study. Airborne dust was collected every month, for 24-hour periods.

The presence of PM_{10} in the air samples and the concentration per unit volume were determined using the Equal Pay Act-29 technique. The presence of Al, As, Cd, Cu, Fe, Pb and Zn heavy metals in PM_{10} and their amounts per unit volume were determined using Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS). Hg was determined using cold vapor Atomic Absorption Spectroscopy. The long-term values per year were calculated using the monthly results. The airborne measurements were made between November 2009 and February 2012.

Mothers and Newborns Participating in the Study

In the second stage, volunteer pregnant women living within a 500m radius of the air sampling locations were recruited for the study. Selection criteria for participants were as follows: in second trimester of pregnancy, not exposed to heavy metals occupationally, non-smokers, 18 to 35 years of age, and without chronic disease. A total of 161 mothers were interviewed in the industrial district (Dilovasi). Fifty-nine of those interviewed met the selection criteria and agreed to participate in the research. Twenty-three mothers withdrew during follow-up for various reasons. Follow-ups were completed with the remaining 39 mothers, and colostrum and meconium samples were collected. A total of 95 mothers were interviewed in the non-industrial district (Kandira). Twenty-two of those interviewed met the selection criteria and volunteered to participate in the study. Four mothers withdrew or became ineligible for various reasons. Follow-ups were completed with the 18 remaining mothers in the Kandira, and the samples were taken. One of the mothers was unable to provide a colostrum sample during the first 5 days after delivery. A total of 56 colostrum samples (39 from the Dilovasi and 17 from the Kandira) were taken and analyze (Figure 1).

The first pregnant woman was enrolled in June 2009 and gave birth in October 2009, and the last woman enrolled in January 2011 and gave birth in April 2011. Meconium samples taken from 8 out of the 39 newborns in Dilovasi were unsuitable for analysis due to unfavorable collection, storage and/or transportation conditions. A total of 49 meconium samples (31 samples from the Dilovasi and 18 from the Kandira) were analyzed (Figure 1).

A questionnaire was completed by the pregnant women to gather information about the socio-demographic profile of the pregnant woman and her husband (age, educational level, occupation, former places and durations of residence, current place and duration of residence, household's total monthly income, etc.), the house (access to drinking water, existence of toilet facilities, type of heating system, etc.), reproductive history (number of marriages, length of marriage, number of pregnancies, number of live births, etc.), nutritional status (intake of iron and vitamin supplementation, type of cooking, etc.), smoking, alcohol consumption habits and use of addictive substances prior to pregnancy. Exposure to second hand smoke and the smoking status of the husband were also determined through this questionnaire.

The pregnant women were followed up with monthly until delivery. The weight and blood pressure of the pregnant woman and maternal and fetal hearth rates were measured. Iron, calcium and folic acid intake by the pregnant women, the presence of infection, edema and varicose veins was determined during each follow-up examination.

At birth, APGAR evaluations were performed and weight, length and head circumference were determined for each newborn. The growth and development of the newborns was then tracked at quarterly intervals for 18 months. From the sixth month onwards, physical examinations to evaluate the psychomotor development of the infants were performed by pediatric neurology specialists. BAYLEY tests were also carried out by expert psychologists.

Colostrum and meconium sampling and analysis

The mothers manually expressed 10 ml of colostrum into sterilized polyethylene tubes for the first 4 days postpartum. The determi-

Table 1. PM_{10} and heavy metal concentrations in the districts of Kocaeli (November 2009-February 2012)

	Industrial district (Dilovasi) Mean ± SD (range)	Non industrial district (Kandira) Mean ± SD (range)
PM_{10} ($\mu g/m^3$)	124.08 ± 80.19 (33.00-376.00)	54.13 ± 61.96 (9.00-320.00)
Al (ng/m^3)	3933.80 ± 3504.29 (19.00-11262.80)	2422.63 ± 3417.14 (18.00-12595.30)
As (ng/m^3)	20.79 ± 19.96 (1.00-80.00)	9.74 ± 11.87 (0.80-34.40)
Cd (ng/m^3)	2.68 ± 3.25 (0.10-17.00)	0.82 ± 0.72 (0.10-2.10)
Cu (ng/m^3)	172.49 ± 370.58 (11.30-1891.10)	28.30 ± 43.23 (0.10-139.40)
Fe (ng/m^3)	4438.36 ± 2511.24 (237.1-9235.00)	699.16 ± 435.64 (44.00-1694.90)
Hg (ng/m^3)	2.15 ± 0.68 (1.80-4.50)	1.87 ± 0.10 (1.70-2.10)
Pb (ng/m^3)	155.02 ± 224.24 (5.00-1118.00)	19.54 ± 36.48 (4.3-193.50)
Zn (ng/m^3)	1777.97 ± 2982.47 (19.00-15189.00)	363.20 ± 725.69 (18.00-3638.00)

nation of presence of the heavy metals in the newborns meconium and measurement of their concentrations was to detect intrauterine exposure (Harries, 1978; Anonymous, 1998; Haram-Mourobet, Harper, Wapnir, 1998).

The meconium samples that did not make contact with a diaper were taken within the first 4 days after birth using non-metallic (glass and/or polyethylene) loops and placed into sterilized polyethylene containers. All of the samples were frozen immediately, and then stored in deep-freezers at a constant temperature of -18℃ at the Kocaeli University Faculty of Medicine. The samples were transported in groups to the TÜBİTAK Bursa Test and Analysis Laboratory (BUTAL) for analysis. The cold chain was kept during transport of samples.

The presence and concentrations of Al, As, Cd, Cu, Fe, Hg, Pb and Zn in the samples were determined at TÜBİTAK-BUTAL. Once received, the frozen samples were freeze-dried by lyophilization at -48℃ for 24 hours. The samples were then burned in a Milostone microwave oven. Cd, Hg, Pb and As were determined using ICP-MS, while Al, Fe, Cu and Zn were determined by inductively coupled plasma-optical emission spectroscopy-ICP-OES. The laboratory analysts conducted a blind analysis on the submitted samples. The names of the districts from which the samples have been collected were kept hidden from the analysts.

The heavy metal concentrations in colostrum and meconium were calculated on a dry weight basis. Colostrum heavy metal data ($\mu g/g$ dry weight) was divided by a factor of 7.5 to calculate wet weight ($\mu g/L$) (Jensen 1991; Gundacter, Pietsching, Witmann, Lischka, Salzer, Hohenauer, Schuster, 2002).

Ethical considerations

Kocaeli University Human Research Ethics Committee gave ethical clearance for this study (Approval No. IAEK 8112/06.05.2008). Verbal consent was obtained from the property owners at the sampling locations to ensure security and provide energy for the measurement equipment that would be installed every month. The volunteer pregnant women and their husbands were informed of all stages of the research. "Informed Consent Forms" were signed by the pregnant women who agreed to participate in the study.

RESULTS

The mean PM_{10} and heavy metal concentration in the air in the industrial district measured: PM_{10}:124.08 $\mu g/m^3$, Al:3933.80 ng/m^3, As:20.79 ng/m^3, Cd:2.68 ng/m^3, Cu:172.49 ng/m^3, Fe:4438.37 ng/m^3, Hg:2.15 ng/m^3, Pb:155.02 ng/m^3, and Zn:1777.97 ng/m^3; and in the non-industrial district, PM_{10}:54.13 ug/m^3, Al:2422.63 ng/m^3, As:9.74 ng/m^3, Cd:0.82 ng/m^3, Cu:28.30 ng/m^3, Fe:699.16 ng/m^3, Hg:1.87 ng/m^3, Pb:19.54 ng/m^3, and Zn: 363.20 ng/m^3 (Table 1).

Table 2. The characteristics of the study population

Characteristics	Industrial district (Dilovasi) (N = 39) Mean ± SD (range), N (%)	Non industrial (Kandira) (N = 18) Mean ± SD (range), N (%)
Mothers		
Age(y)	27.1 ± 4.4 (19.2-34.8)	27.5 ± 4.2 (21.3-35.9)
Housewife	38 (97.4)	16 (88.9)
Education level ≤ 8 years	35 (89.7)	13 (72.2)
Monthly income, $/person	143 ± 79.7 (29-397)	276 ± 245.1 (84-882)
Duration of living in district (y)	12.8 ± 9.1 (0.7-30.0)	16.9 ± 13.6 (0.4-35.9)
Primiparous	11 (28.2)	8 (44.4)
Gravity	2.7 ± 1.4 (1.0-6.0)	1.9 ± 1.0 (1.0-4.0)
Parity	2.0 ± 0.9 (1.0-4.0)	1.5 ± 0.7 (1.0-3.0)
Birth interval (year)		
≤ 2	11 (35.5)	5 (50.0)
> 2	20 (64.5)	5 (50.0)
Smoking before pregnancy	11 (28.2)	3 (16.7)
Passive smoking during pregnancy	18 (46.2)	5 (27.8)
Intake of vitamin supplement in pregnancy	3 (7.7)	13 (72.2)
Intake of iron supplement in pregnancy	17 (43.6)	18 (100.0)
Newborns		
Gender, girls	18 (46.2)	11 (61.1)
Gestational age (wk)	39.8 ± 1.4 (36.6-44.4)	39.7 ± 1.1 (38.0-42.6)
Birth weight (g)	3335.1 ± 415.5 (2400-4510)	3287.8 ± 218.7 (2950.0-3740.0)
Birth length (cm)	50.2 ± 1.8 (46.0-55.0)	50.7 ± 1.3 (48.0-54.0)
Head circumference at birth (cm)	34.8 ± 1.6 (31.5-38.0)	35.0 ± 1.0 (33.0-37.0)
Place and type of delivery		
Hospital		
Vaginal	24 (61.54)	11 (61.11)
Caesarean	13 (33.33)	7 (38.89)
Home	2 (5.13)	-

The mean age of the pregnant women in the industrial district (± SD) was 27 ± 4 years (min-max = 19-35). The majority of the pregnant women and husbands (90% and 87%, respectively) had less than 8 years of formal education. Only 3% of the pregnant women were working. The mean monthly per capita income was 143 US$. About one third of the pregnant women reported smoking before pregnancy. The mean length of residence in the industrial district was 13 years. Twenty-one percent of the pregnant women were primiparous. The mean number of pregnancies was 2.7, whereas the mean number of births was 1.7. The mean birth interval was 3.7 years. The birth interval was more than 2 years in 65% of the pregnant women. Forty-six percent of the pregnant women were passive smokers during pregnancy, 7.7% were taking vitamin supplements regularly, and 44%

Table 3. Levels of heavy metals in meconium of newborns in the districts of Kocaeli (µg/kg.).

Heavy metals	Industrial district (Dilovasi) (N = 31) > LOQ N (%)	Min	Percentiles 25p	50p	75p	Max	Non industrial district (Kandira) (N = 18) > LOQ N (%)	Min	Percentiles 25p	50p	75p	Max
Al [a]	20 (64.5)	< LOQ	< LOQ	3000	5400	40700	8 (44.4)	< LOQ	< LOQ	< LOQ	3225	22800
As [b]	27 (87.1)	< LOQ	38	60	72	110	16 (88.9)	< LOQ	32	70	102.5	130
Cd [b]	29 (93.5)	< LOQ	12	30	67	135	16 (88.9)	< LOQ	8	35.5	47	69
Cu [a]	31 (100.0)	16700	44600	71000	122000	264000	18 (100.0)	33000	50675	67050	114000	154000
Fe [a]	31 (100.0)	18400	30400	56400	78800	354000	18 (100.0)	20300	43450	60750	81575	124000
Hg [b]	13 (41.9)	< LOQ	< LOQ	< LOQ	14	160	6 (33.3)	< LOQ	< LOQ	< LOQ	10.5	44
Pb [b]	28 (90.3)	< LOQ	29	84	160	429	15 (83.3)	< LOQ	14.5	41	75.75	330
Zn [a]	31 (100.0)	48300	162000	229000	420000	745000	18 (100.0)	147000	211250	244500	305000	471000

LOQ: Limits of quantitation

[a] LOQ for Al, Cu, Fe, Zn:< 1 µg/g

[b] LOQ for As, Cd, Hg, Pb:< 0.005 µg/g

Table 4. Levels of heavy metals in colostrum milk from pregnant women living in the districts of Kocaeli (µg/l.).

Heavy metals	Industrial district (Dilovasi) (N = 39) > LOQ N (%)	Min	Percentiles 25p	50p	75p	Max	> WHO recommended limit level[a] N (%)	Non industrial district (Kandira) (N = 17) > LOQ N (%)	Min	Percentiles 25p	50p	75p	Max	>WHO recommend-ed limit level[a] N (%)
Al [b]	18 (46.2)	< LOQ	< LOQ	< LOQ	306.7	5360.0		7 (41.2)	< LOQ	< LOQ	< LOQ	560.0	1813.3	
As [c]	35 (89.7)	< LOQ	13.3	21.3	34.4	181.3	35 (89.7)	15 (88.2)	< LOQ	9.1	18.7	27.3	66.7	15 (88.2)
Cd [c]	15 (38.5)	< LOQ	< LOQ	< LOQ	1.1	4400.0	13 (33.3)	2 (11.8)	< LOQ	< LOQ	< LOQ	< LOQ	3.5	2 (11.8)
Cu [b]	39 (100.0)	293.3	533.3	653.3	853.3	1706.7	37 (94.9)	17 (100.0)	320.0	726.7	853.3	1020.0	1680.0	17 (100.0)
Fe [b]	39 (100.0)	333.3	573.3	786,7	1280.0	4373.3	2 (53.8)	17 (100.0)	320.0	740.0	946.7	1226.7	6026.7	14 (82.4)
Hg [c]	17 (43.6)	< LOQ	< LOQ	< LOQ	2.4	26.7	13(33.3)	8 (47.1)	< LOQ	< LOQ	< LOQ	6.1	66.7	8 (47.1)
Pb [c]	37 (94.9)	< LOQ	3.3	8.7	18.7	96.0	23 (60.0)	16 (94.1)	< LOQ	3.9	10.1	14.9	26.7	12 (70.6)
Zn [b]	39 (100.0)	840.0	3506.7	4760.0	7400.0	19333.3	34 (87.2)	17 (100.0)	546.7	1380.0	3360.0	4773.3	11986.7	12 (70.6)

LOQ: Limits of quantitation

[a] WHO: WHO recommended limit level for As:< 0.6 µg/l, for Cd:< 1 µg/l, for Cu:< 310 µg/l, for Fe:< 720 µg/l, for Pb:< 5 µg/l, for Hg: < 1.7 µg/l, for Zn:< 2000 µg/l

[b] LOQ for Al, Cu, Fe, Zn: < 1 µg/g

[c] LOQ for As, Cd, Hg, Pb: < 0.005 µg/g

were taking iron supplements. Only 7.7% of the pregnant women were taking both vitamin supplements and iron regularly (Table 2).

About half of the newborns born to women in the industrial district were female. The mean birth weight (± SD) of the newborns was 3.335 ± 416 g (min-max = 2400-4510). The mean birth length (± SD) was 50 ± 2 cm (min-max = 46-55). The mean head circumference (± SD) was 35 ± 2 cm (min-max=32-38). The mean gestational age (± SD) was 39.8 ± 1.4 weeks (min-max = 36.6-44.4). Thirty-three percent of the newborns were delivered by cesarean section, and 5% of the infants were born at home (Table 2).

The mean age of the pregnant women in the non-industrial district (± SD) was 28 ± 4 years (min-max = 21-36). Seventy-two percent of the pregnant and 61% of their husbands had less than 8 years of formal education. Only 11% of the pregnant women were working. The mean monthly per capita income was $276 US. Seventeen percent of the pregnant women reported smoking before pregnancy. The mean length of residence in non-industrial district was 19 years. Forty-four percent of the mothers were primiparous. The mean number of pregnancies was 1.9 whereas the mean number of births was 1.4. The mean birth interval was 3.0 years. The birth interval was more than 2 years in 50% of the mothers.

Twenty-eight percent of the pregnant women were passive smokers during pregnancy, 72% were taking vitamin supplements regularly and 100 of the pregnant women regularly used iron supplements. Seventy-two percent of the pregnant women were taking both vitamin supplements and iron regularly (Table 2).

Sixty-one percent of the newborns born to women in the non-industrial district were female. The mean birth weight (± SD) of the newborns was 3.288 ± 219 g (min-max = 2950-3740). The mean birth length (± SD) was 51 ± 1 cm (min-max = 48-54). The mean head circumference (± SD) was 35 ± 1 cm. (min-max = 33-37). The mean gestational age (± SD) was 39.7 ± 1.1 weeks (min-max = 38.0-42.6).

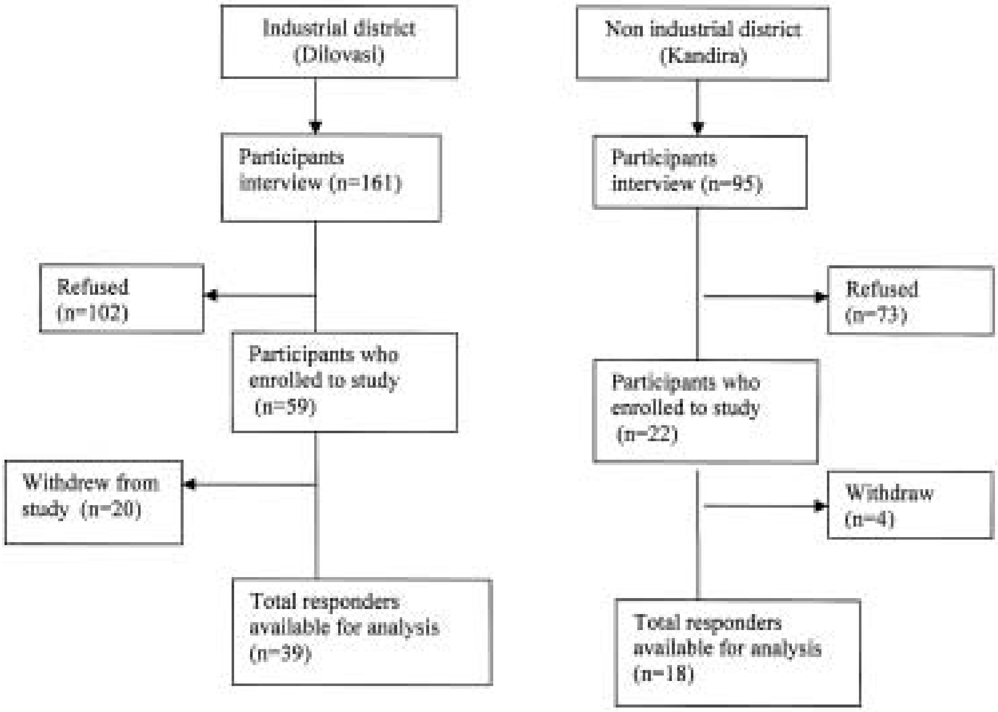

Figure 1. Mothers and Newborns Participating in the Study

Thirty-nine percent of the newborns were delivered by cesarean section (Table 2).

Pb, Cd, As, Al and Hg were in 90%, 94%, 87%, 65% and 42% of the meconium samples from newborns in the industrial district, respectively. In the non-industrial district, Pb, Cd, As, Al and Hg were in 83%, 89%, 89%, 44% and 33% to Hg (Table 3).

The concentrations of Cu, Fe and Zn were higher than the detection limit (> 1 μg/g) in all samples (100%). Pb, As, Cd and Hg levels were above the detection limit (> 0.005 μg/g) in 90%, 39%, 44% and 95% of the colostrum samples taken in the industrial district, respectively. For the samples collected in the non-industrial district, As, Cd, Hg and Pb were above the detection limit in 88%, 12%, 47 % and 94% of the colostrum samples, respectively. In the colostrum samples collected in the industrial district, the median (25-75 percentile) As, Cu, Fe, Pb and Zn levels were 21.3 (13.3-34.4) μg/L, 653.3 (533.3-853.3) μg/L, 786.7 (573.3-1280.0) μg/L, 8.7 (3.3-18.7) μg/L and 4760.0 (3506.7-7400.0) μg/L, respectively. In the colostrum samples collected in the non-industrial district the median (25-75 percentile) As, Cu, Fe, Pb and Zn levels were 18.7 (9.1-27.3) μg/L, 853.3 (726.7-1020.0) μg/L, 946.7 (740.0-1226.7) μg/L, 10.1 (3.9-14.9) μg/L and 3360.0 (1380.0-4773.3) μg/L, respectively.

DISCUSSION

In order to protect human health, the World Health Organization (WHO) (2006) has defined an average annual limit of 20 $\mu g/m^3$ for PM_{10} and the European Commission (EC) (2008) has defined an average annual limit of 6 ng/m^3 for As. In this study, PM10 and As concentrations were 6.2 and 3.5 times higher, respectively, than these limits in the industrial district. In the non-industrial district, the PM_{10} and As levels were 2.7 and 1.6 times higher, respectively, than the WHO and the EC limits. Therefore, it can be concluded that unhealthy levels of air pollution are found in both districts, although at higher concentrations in the industrial district. This is as an indicator of the risk to human health created by industrial enterprises, not only to their own territories but also in the surrounding areas.

The purpose of determining the presence and measuring the concentration of heavy metals in the newborns' meconium and was to detect intrauterine exposure. The concentrations of heavy metals detected in the meconium samples indicate that the contamination began in the intrauterine period (Harries, 1978; Anonymous, 1998; Haram-Mourobet *et al*., 1998). Cu, Fe and Zn were identified in meconium samples collected from both districts. However, greater exposures were found in the industrial district, than the non-industrial district (90% versus 83% for Pb, 94% versus 89% for Cd, 87% versus 89% for As, 65% versus 44% for Al and 42% versus 33% for Hg). Pb, Cd, Zn, Cu and Fe were in all meconium samples taken from newborns delivered in Kocaeli in 2001 (Turker *et al*., 2006). These findings are consistent with the results of the present study and indicate that heavy metal exposure is a persistent problem.

In this study, As, Cd, Cu, Fe Hg, Pb and Zn concentrations in the colostrum samples from pregnant women in both districts were higher than the limit defined by the WHO (WHO 1998). Pb and Cd levels in breast milk samples taken from mothers in Turkey at two months postpartum were also higher than the WHO limits (Orun *et al*., 2011). In the study, the mean Hg level was 2.29 μg/L in colostrum samples collected from the industrial district and 8.85 μg/L in samples collected from the non-industrial district. These values are in the range of those found in another Turkish study, where the mean Hg concentration found in breast milk sampled at 10-20 days postpartum was 3.42 μg/L (Yalcin, *et al*., 2010).

In another study in Turkey (Ankara), the levels of Cd, Cu, Fe and Zn were much lower than those found in colostrum from mothers in the industrial area in this study, while Pb levels were the same (Turan *et al*., 2001). The Cd and Pb levels were higher in the Ankara study than in the samples from the non-industrial area in our study, while the Cu, Fe and Zn levels were lower.

CONCLUSION

In this study, PM_{10} levels were detected in both industrial and non-industrial districts located within the boundaries of an industrial city, indicating that it is necessary to take measures to reduce the adverse health effects of air pollution, and reduce or eliminate the main source of the pollution.

Meconium is a convenient matrix for determining heavy metal exposure in newborns. Colostrum is also a convenient matrix for determining heavy metal exposure in both mothers and newborns. Detection of heavy metal (Al, As, Cd, Cu, Fe, Hg, Pb and Zn) exposure in mothers lived in both industrial and non-industrial districts within an industrial city and were not exposed occupationally to heavy metals and in their newborns reveals the existence of a public health problem that should be addressed. In order to safeguard public health, immediate measures should be taken to reduce air pollution.

Further research should be carried out to monitor the effectiveness of the air pollution reduction measures.

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REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). (1999). Toxicological Profile for Mercury. Agency for Toxic Substances and Disease Registry, Division of Toxicology, Atlanta, Georgia.

Agency for Toxic Substances and Disease Registry (ATSDR). (2007). CERCLA priority list of hazardous substances. Agency for Toxic Substances and Disease Registry, Atlanta: Georgia. http://www.atsdr.cdc.gov/ cercla/07list.html) [accessed 20 January 2009].

Ahmad SA, *et al*. (2001). Arsenic in drinking water and pregnancy outcomes. *Environ Health Perspect*, 109(6), 629-631.

Anonymous. (1998). Minerals. *J Nutr*, 128, 2140-2181.

Bell ML, Ebisu K, Belanger K. (2007). Ambient air pollution and low birth weight in Connecticut and Massachusetts. *Environ Health Perspect*, 115(7), 1118-1124.

Calderón J, *et al*. (2001). Exposure to arsenic and lead and neuropsychological development in Mexican children. *Environ Res*, 85(2), 69-76.

Chang CH, Mann DE, Gauteri RF. (1977). Teratogenicity of zinc chloride, 1,10 phenanthroline, and a zinc-1,10- phenanthroline complex in mice. *J Pharm Sci*, 66(12), 1755-1758.

Chen L, Yang W, Jennison BL, Goodrich A, Omaye ST. (2002). Air pollution and birth weight in northern Nevada, 1991-1999. *Inhal Toxicol*, 14(2), 141-157.

Conceição GM, Miraglia SG, Kishi HS, Saldiva PH, Singer JM. (2001). Air pollution and child mortality: a time-series study in So Paulo, Brazil. *Environ Health Perspect*, 109 (Supl 3), 347-350.

Cox DH, Schlicker SA, Chu RC. (1969). Excess dietary zinc for the maternal rat, and zinc, iron, copper, calcium, and magnesium content and enzyme activity in maternal and fetal tissues. *J Nutr*, 98(4), 459-466.

Counter SA, Buchanan LH. (2004). Mercury exposure in children: A review. *Toxicol Appl Pharmacol*, 198(2), 209-230.

Dockery DW, Pope CA. (1994). Acute respiratory effects of particulate air pollution. *Annu Rev Public Health*, 15, 107-132.

Dugandzic R, Dodds L, Stieb D, Smith-Doiron M. (2006). The association between low level exposures to ambient air pollution and term low birth weight: A retrospective cohort study. *Environ Health*, 5, 1-8. doi:10.1186/1476-069X-5-3

Ermis H, Cizmecioglu F, Bertman S, Guray O. (1994). Investigation of the levels in the breast milk and umbilical cord blood. *J Ist Fac Med*, 57, 22-25.

European Commission (EC). (2008). Air quality standarts. http://ec.europa.eu/environment/air/quality/standards.htm [accessed 27 December 2010]

Goldman LR, Shannon MW. (2001). Technical report: mercury in the environment: implications for pediatricians. *Pediatrics*, 108(1), 197-205.

Gouveia N, Bremner SA, Novaes HM. (2004). Association between ambient air pollution and birth weight in Sao Paulo, Brazil. *J Epidemiol Community Health*, 58(1), 11-17.

Gundacter C, *et al*. (2002) Lead and mercury in breast milk. *Pediatrics*, 110(5), 873-878.

Hamzaoglu O, Etiler N, Yavuz CI, Caglayan C. (2011). The causes of deaths in an industry-densed area: example of Dilovasi (Kocaeli). *Turk J Med Sci*, 41(3), 369-375.

Hansen C, Neller A, Williams G, Simpson R. (2006). Maternal exposure to low levels of ambient air pollution and preterm birth in Brisbane, Australia. *BJOG*, 113(8), 935-941.

Haram-Mourobet S, Harper RG, Wapnir RA. (1998). Mineral composition of meconium: effect of prematurity. *J Am Coll Nutr*, 17(4), 356-360.

Harries JT. (1978). Meconium in health and disease. *Br Med Bull*, 34(1), 75-79.

Hopenhayn-Rich C, Browning SR, Hertz-Picciotto I, Ferreccio C, Peralta C, Gibb H. (2000). Chronic arsenic exposure and risk of infant mortality in two areas of Chile. *Environ Health Perspect*, 108 (7), 667-673.

Jarup L. (2003). Hazards of heavy metal contamination. *Br Med Bull*, 68, 167-82.

Jensen AA. (1991). Levels and trends of environmental chemicals in human milk. In AA Jensen, SA Slorach (Eds.), Chemical contaminants in human milk. (p. 45-198). Boston: CRC Press Inc.

Jiang LL, *et al*. (2007). A time series analysis of outdoor air pollution and preterm birth in Shanghai, China. *Biomed Environ Sci*, 20(5), 426-431.

Jugo S. (1977). Metabolism of toxic heavy metals in growing organisms: A review. *Environ Res*, 13(1), 36-46.

Kandira District Administration (KDA). (2011). http://www.kandira.gov.tr/site/?sec=icerikdetay&id=24 yıl [accessed 9 August 2011].

Kocaeli Champer of Industry (KCI). (2011). About Kocaeli. http://www.kosano.org.tr/tr/Anasayfa.aspx.) [accessed 9 August 2011]

Kwok RK, Kaufmann RB, Jakariya M. (2006). Arsenic in drinking water and reproductive health outcomes: a study of participants in the Bangladesh Integrated Nutrition Programme. *J Health Popul Nutr*, 24(2), 190-205.

Leem JH, *et al*. (2006). Exposures to air pollutants during pregnancy and preterm delivery. *Environ Health Perspect*, 114(6), 905-910.

Milton AH, Smith W, Rahman B, Hasan Z, Kulsum U, Dear K, Rakibuddin M, Ali A. (2005), Chronic arsenic exposure and adverse pregnancy outcomes in Bangladesh. *Epidemiology*, 16(1), 82-86.

Nayak P. (2002). Aluminum: impacts and disease. *Environ Res*, 89(2), 101-115.

Needleman HL, Gatsonis CA. (1990). Low-level lead exposure and the IQ of children. *JAMA*, 263(5), 673-678.

Orün E, *et al*. (2011). Breast milk lead and cadmium levels from suburban areas of Ankara. *Sci Total Environ*, 409(13), 2467-2472.

Rahman A, *et al*. (2007). Association of arsenic exposure during pregnancy with fetal loss and infant death: a cohort study in Bangladesh. *Am J Epidemiol*, 165(12), 1389-1396.

Ritz B, Yu F, Chapa G, Fruin S. (2000). Effect of air pollution on preterm birth among children born in Southern California between 1989 and 1993. *Epidemiology*, 11(5), 502-511.

Ronchetti R, Zu *et al*. (2006). Children's health and mercury exposure. *Acta Pœdiatr, Suppl*, 95(453), 36- 44.

Schoeters G, *et al*. (2006) Cadmium and children: Exposure and health effects. *Acta Pædiatr*, 195(453), 50-54.

Sagiv SK, *et al*. (2005). A time series analysis of air pollution and preterm birth in Pennsylvania, 1997-2001. *Environ Health Perspect*, 113(5), 602-606.

Salam MT, Millstein J, Li YF, Lurmann FW, Margolis HG, Gilliland FD. (2005) Birth outcomes and prenatal exposure to ozone, carbon monoxide, and particulate matter: results from the Children's Health Study. *Environ Health Perspect*, 113(11), 1638-1644.

Turan S, Saygi S, Kilic Z, Acar O. (2001). Determination of heavy metal contents in human colostrum samples by electrothermal atomic absorption spectrophotometry. *J Trop Pediatr*, 47(2), 81-85.

Turker G, Ergen K, Karakoc Y, Arisoy AE, Barutcu UB. (2006). Concentrations of toxic metals and trace elements in the meconium of newborns from an industrial city. *Biol Neonate*, 89(4), 244-250.

Ursinyova M, Masanova V. (2005). Cadmium, lead and mercury in human milk from Slovakia. Food *Addits Contam*, 22(6), 579-589.

Vichinsky E. (2009). Iron overload and iron chelation therapy in pediatric patients. US *Hemotology*, 2(1), 64-67.

Von Ehrenstein OS, Guha Mazumder DN, Hira-Smith M, Ghosh N, Yuan Y, Windham G, Ghosh A, Hague R, Lahiri S, Kalman D, Das S, Smith AH. (2006). Pregnancy outcomes, infant mortality, and arsenic in drinking water in West Bengal, India. *Am J Epidemiol*, 163(7), 662-669.

Wang A, Holladay SD, Wolf DC, Ahmed SA, Robertson JL. (2006). Reproductive and developmental toxicity of arsenic in rodents: A review. *Int J Toxicol*, 25, 319-331.

WHO. (2006). WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Global update 2005. Summary of risk assessment. Geneva: WHO pub.

WHO. (2006). Preventing disease through healthy environments: Towards an estimate of the environmental burden of disease. Geneva: WHO pub.

WHO. (1998). International programme on chemical Safety. Environmental health criteria 200 Copper. Geneva: WHO pub.

WHO. (1993). Guidelines on studies in environmental epidemiology. Environmental Health Criteria Series No. 27. Geneva: WHO pub.

Woodruff TJ, Grubl J, Schoendorf KC. (1997). The relationship between selected causes of postneonatal infant mortality and particulate air pollution in the United States. Environ Health Perspect, 105(6), 608-612.

Woodruff TJ, Perker JD, Schoendorf KC. (2006). Fine particulate matter (PM2.5) Air pollution and selected causes of postneonatal infant mortality in California. *Environ Health Perspect*, 114(5),786-790.

Yalcin SS, Orun E, Mutlu B, Madendag Y, Sinici I, Dursun A, Ozkara HA, Ustunyurt Z, Kutluk S, Yurdakok K. (2010). Why are they having infant colic? A nested case-control study. *Paediatr Perinat Epidemiol*, 24(6), 584-596.