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Multipathways human health risk assessment of trihalomethane exposure through drinking water

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ABSTRACT

Life-time human health risk of cancer attributed to trihalomethanes in drinking water in an urban-industrialized area of Karachi (Pakistan) was conducted through multiple pathways of exposure. The extent of cancer risk was compared with USEPA guidelines. Human health cancer risk for total trihalomethanes (TTHMs) through ingestion and dermal routes were estimated in "acceptable-low risk" ($\geq$ 1.0E−06; $\leq$ 5.10E−05), whereas through inhalation route it was estimated under "acceptable-high risk" ($\geq$ 5.10E−05; $\leq$ 1.0E−04) category. However, at some industrial–urban areas cancer risk for $CHCl_3$ were estimated under "unacceptable risk" ($\geq$ 1.0E−04) through inhalation route.

1. Introduction

The presence of microbiological organisms is the most common pollution culprit in the urban areas and microorganisms, such as bacteria, viruses, and protozoa can cause serious illnesses and deaths (Uyak et al., 2005). The most common and economic method of disinfection is chlorination (Yang et al., 1998; Hsu et al., 2001; Rodriguez and Serodes, 2001; Hamidin et al., 2008). Although chlorine disinfection reduces mortality and morbidity due to water-borne diseases (Calderon, 2000; Golfinopoulos and Nikolaou, 2005), chlorine can react with natural organic matter (NOM) and form various types of disinfection byproducts (DBPs), chiefly trihalomethanes (THMs). Epidemiological and clinical studies have revealed that several health effects are associated with the exposure to DBPs, such as elevated rates of bladder, colon–rectum and brain cancers (Cantor et al., 1998; McGeehin et al., 1993; Hildesheim et al., 1998; Cantor et al., 1999; Wilkins et al., 1979; Flaten, 1992; King et al., 2000a), cardiac anomalies, stillbirths, miscarriages, low birth weights and pre-term deliveries, and neural tube defects (Mills et al., 1998; Richardson., 2005; King et al., 2000b). Epidemiological data availability in Pakistan from population-based registries is mostly unavailable, and institutional based registries seldom provide estimates of disease distribution. The only population-based cancer registry was established in Karachi, where statistics for 9 years (1995–2003) were published. The population-based cancer registry in Karachi has identified 8 major classes of cancers prevailing in males (lung (11%), oral cavity (13.1%), larynx (6.1%), urinary bladder (4.8%), prostate (4.1%), lymphoma (7%), pharynx (4.3%), colo-rectum (4.4%)) and females (breast (34.6%), oral cavity (8.9%), cervix (4.1%), esophagus (3.7%), ovary (4.2%), lymphoma (3.5%), gall bladder (2.6%), skin (2.6%)). The estimates show that the projected figures for Pakistan are double the estimates by the World Health Organization (WHO). Breast cancer rate among women is high in Karachi (34.6% rate of female cancer), the highest in Asia (Bhurgri, 2004).

Exposures to DBPs can occur throughout a lifetime via multiple pathways, such as water ingestion by the oral route, inhalation through breathing and dermal contact through skin during regular indoor activities, such as showering, bathing and cooking. These chronic exposures to DBPs may pose risks to human health. Traditional risk assessment studies only considered the oral route of water to estimate the life time health risk. However, other routes of DBPs exposure for health risk assessment are now considered in scientific studies (Hsu et al., 2001; Mallika et al., 2008; Uyak, 2006; Lee et al., 2004; Weisel and Jo, 1996; Weisel et al., 1999).

The study area, which encompasses the metropolitan area of

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Karachi along with its suburbs, is the world's second most populated city, (estimated at 20 million, http://www.karachicity.gov.pk/), spread over 3530 km^2. Karachi is situated at (24°45′N–25°01′N and 66°55′E–67°15′E). The main source of water supply to the city of Karachi is from surface water (i.e., Indus River through Kenjhar and Haleji Lakes, and Hub dam built on Hub River). The present study was aimed at using a multi-pathway exposure model on the basis of our earlier studies (Siddique et al., 2012) for lifetime human health risk assessment to evaluate and quantify the adverse effect of trihalomethanes (THMs) in tap water.

2. Materials and methods

Drinking water samples from various areas of the city (Fig. 1) were collected in headspace-free borosilicate amber glass bottles containing about 1.7 mL sodium thiosulfate (10%) quenching solution (APHA, 1992; Rodriguez and Serodes, 2001). Once collected, samples were stored in the dark at 4 °C and carried to the laboratory for analytical procedures. A modified EPA Method (EPA 551.1) was applied for the assessment of THMs (MTBE) (Nikolaou et al., 2002; Golfinopoulos et al., 2005). Two milliliter of MTBE extraction solvent were added to 35 mL of water sample in a 40 mL glass vial containing anhydrous sodium sulfate as drying agent. For phase separation, the vial was shaken for 1 min and left undisturbed for further 2–3 min. The upper 1 μL organic layer was injected into HP 5890 gas chromatograph (GC) equipped with DB-5 chromatographic column and electron capture detector (ECD). Analysis conditions: injection on column volume 2 μL; oven temperature 30 °C for 10 min, 30–41 °C at 3 °C/min; hold at 41 °C for 6 min; 41–81 °C at 5 °C/min; 81–180 °C at 25 °C/min and hold at 180 °C for 6 min; carrier gas Helium at a rate of 1.5 mL/min; detector temperature of 275 °C. A DB-1701 capillary column (30 m, 0.32 mm i.d., 0.25 μm film thickness) was used for the confirmation analysis. Stock THM standards were obtained from AccuStandard and were diluted to different concentration levels. The identification of individual THMs was based on the comparison of retention times of THMs in samples with those of THM standards.

Table 1
Average THMs level (μg/L) in water samples of different localities in Karachi.

Locality	*n*	Average THMs level (μg/L)						
		$CHCl_3$	SD	$CHBrCl_2$	SD	$CHBr_2Cl$	SD	Total THMs
Hawk's bay	8	46.2	*15.8*	3.0	*0.37*	0.48	*0.83*	49.7
SITE	12	61.2	*23.0*	2.7	*0.43*	1.5	*0.27*	65.4
Orangi/Baldia	16	76.8	*26.6*	4.1	*1.6*	2.6	*0.97*	83.5
Saddar	20	72.5	*25.0*	3.3	*1.4*	2.0	*0.81*	77.8
Jamshaid Town	20	55.2	*27.9*	2.7	*0.65*	1.2	*0.35*	59.1
Liaqutabad	8	90.8	*40.0*	2.8	*0.64*	1.5	*0.29*	95.0
Mansoora	8	98.5	*41.5*	3.2	*0.94*	1.8	*0.52*	103.5
Taimuria	16	79.3	*40.9*	3.1	*1.1*	1.5	*0.53*	83.8
North Karachi	12	62.4	*29.7*	4.5	*1.5*	2.4	*0.87*	69.3
DHA/Clifton	13	71.1	*26.0*	3.00	*1.5*	1.7	*1.09*	75.8
Korangi/Landhi	24	56.2	*21.9*	2.9	*1.2*	1.6	*0.81*	60.7
Shah Faisal/ Airport	27	79.8	*30.8*	3.1	*0.89*	1.7	*0.54*	84.6
Gulshan e Iqbal	9	66.5	*31.8*	3.5	*1.1*	2.3	*0.14*	72.3
Malir	8	49.7	*20.5*	3.2	*1.5*	2.0	*0.97*	54.9
Ibrahim Hydri	11	82.2	*37.7*	2.6	*2.1*	1.7	*1.24*	86.5
LITE/Cattle colony	8	63.3	*27.6*	3.2	*1.2*	1.8	*0.76*	68.3
Port Qasim	16	90.0	*55.3*	2.7	*0.82*	1.7	*0.20*	94.4

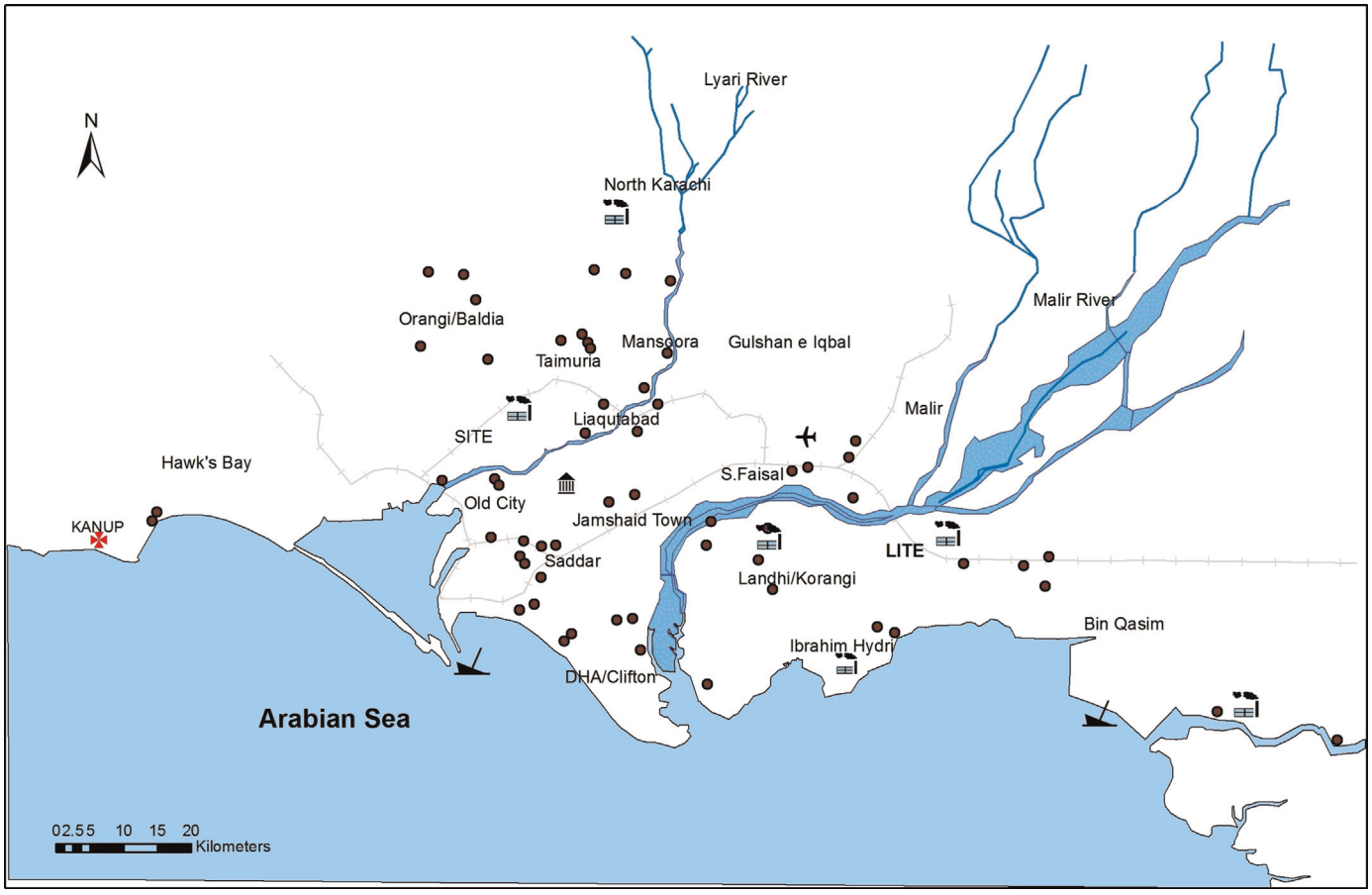

Fig. 1. Map of the sampling locations.