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Cancer Incidence in a Population Living Near a Petrochemical Facility and Oil Refinery

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A B S T R A C T

There is growing concern that pollution from petrochemical and oil refinery installations in Pančevo (Serbia) has increased the incidence of various diseases including cancer. The aim of our study was to investigate cancer incidence in Pančevo and to compare it with the region of central Serbia. Cancer incidence data were obtained from the corresponding Serbian Cancer Registries. Systematic local monitoring of benzene, toluene and methyl mercaptane in the atmosphere within Pančevo's industrial area indicated that the average monthly and yearly concentrations often exceeded permitted levels proposed by EU standards (5 μgm^{-3}). Cancer incidence was lower in Pančevo than in central Serbia (the standardised incidence for all types of cancers in Pančevo was 218.3 and in central Serbia it was 241.7 per 100,000 inhabitants). The available data do not allow us to correlate air pollution in Pančevo with increased cancer incidence.

***Key words**: cancer incidence, petrochemical industry, oil refinery, environmental exposure, benzene exposure*

Introduction

Numerous studies have shown that living in the vicinity of various industrial complexes causes health disorders. In the 1980s residential proximity to petrochemical industries may have contributed to lung cancer mortality in Louisiana (USA)[1]. A study in Teeside (UK) concerning the effects of living near a constellation of petrochemical, steel and other industries concluded that lung cancer risk was moderately increased[2]. In a Korean study long-term exposure to PM(10) was significantly associated with female lung cancer incidence in seven Korean metropolitan cities[3]. In a Japanese study a significant correlation was found between the concentration of suspended particulate matter and lung, breast, endometrial and ovarian cancer in females[4]. In some locations in Europe the proportion of lung cancers attributable to urban air pollution has been calculated to be as high as 10.7%[5]. In Malagrotta (a suburb of Rome, Italy) where a large waste disposal site, a waste incinerator plant and an oil refinery are three major sources of air pollution, no association between proximity to the industrial sites and mortality with respect to cancer of the liver, larynx, lung, kidney, lymphatic and hematopoietic systems was demonstrated[6]. However, laryngeal cancer mortality declined with increasing distance from the sources of air pollution. A case-controlled study in Spain revealed small to moderate positive associations between several indices of air-pollution and bladder cancer[7]. A study in Bangkok[8] (Thailand) revealed an association between PM (10), PM (2.5) and daily occurrences of upper and lower respiratory symptoms in school children, nurses and adults.

Pančevo is a small city in Serbia located 20 km Southeast from Belgrade. It is a good example of a location where both an oil refinery and a petrochemical complex are in close proximity to urban life. The southern part of city known as the Southern Industrial Zone is the loca-

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tion of Serbia's largest and most important oil refinery and petrochemical complex. In the past the Southern Industrial zone was a peripheral suburb of Pančevo. During the last three decades the Southern Industrial Zone has become surrounded by residential areas, including the nearby village of Vojlovica (Figure 1). Due to the predominating southeasterly wind, the inhabitants of both Pančevo and Vojlovica are constantly exposed to emissions from both the oil refinery and the petrochemical complex.

Public health professionals, the media and local statutory agencies have been involved in long-standing and long-term debates regarding the contribution of industrial pollution to the possible high incidence of different diseases in Pančevo. To date, no relevant data has been published.

The aim of this study was to investigate the incidence of cancer in Pančevo and to compare it with data from the Central Serbia.

Methods

Benzene, toluene and methyl mercaptane monitoring was performed at three selected sites in Pančevo during 2004–2007. In addition, SO_2, NH_3, NO, CO, O_3 and PM (10) analysis was also performed[9]. Systematic monitoring was carried out at sites I and II, (fire brigade headquarters and Vojlovica), both located near the industrial complex and downwind of the Southern Industrial Zone. Monitoring site III (Starčevo) was located to the south east of the industrial complex and upwind of the Southern Industrial Zone. The monitoring systems were provided and installed by »MLU« (sites I and II) and by »Project Automation S.P.A Italy« (site III). All measurements were automatically collected and analysed by EnviMan ComVisioner and EnviMan Reporter (OPSIS) software. The meteorological station in Pančevo has no anemograph. Therefore, all the data concerning wind-speed and direction in Pančevo were collected in the meteorological station in Belgrade.

Fig. 1. Map of Pančevo.

Cancer incidence data were obtained from the Cancer Registry of the Serbian Institute of Public Health (for central Serbia) and from the Cancer Registry of Vojvodina (for Pančevo) during the period 2003–2008. The number of new cases with cancer and their characteristics according to age and sex are presented as averages.

The population estimates for the calculation of values were based on official data obtained from the relevant authorities in central Serbia and Pančevo. When calculating incidence rates, World population direct standardisation was applied using seventeen locations of highest cancer incidence for both sexes. The value of the standardised incidence rate was ranked by size order.

χ^2-test has been used in comparison of data on cancer incidence.

Results

Benzene, toluene and methyl mercaptane monitoring clearly indicated that the levels of air pollution at sites I and II were higher than at site III (Table 1). The average concentrations of benzene at sites I and II were above 5 μgm^{-3} almost every month during the study period (except in August 2005 and April-May 2006). Toluene concentrations reflected benzene concentrations (higher at sites I and II than at site III). Extremely high benzene concentrations were frequently recorded, the two highest values being 160.5 and 125.88 μgm^{-3}. The average toluene concentrations were generally lower than the benzene concentrations at each site. During the study period toluene was rarely detected at site III. Methyl mercaptane was rarely detected at all sites (mainly at site I).

During the study period (2003–2008) in central Serbia there were an average of 11421.0 new male cancer patients *per* year (the crude incidence rate was 425.1 and the standardised incidence rate was 241.7 in 100,000 inhabitants). During the same period in the municipality of Pančevo there were an average of 216.2 new male cancer patients *per* year (the crude incidence rate was 361.2 and the standardised incidence rate was 218.3) (Table 2). The difference between central Serbia and Pančevo cancer incidence was statistically significant ($p<0.01$).

The average number of new female cancer patients *per* year during the period 2003–2008 in central Serbia was 11257.9 (the crude incidence rate was 404.6 and the

TABLE 1
BENZENE, TOLUENE AND METHYL MERCAPTANE CONCENTRATIONS IN PANČEVO DURING THE PERIOD 2004–2007

Year/Month		2004			2005			2006			2007		
		Average monthly concentration (μgm^{-3})			Average monthly concentration (μgm^{-3})			Average monthly concentration (μgm^{-3})			Average monthly concentration (μgm^{-3})		
		B	T	me-me	B	T	me-me	B	T	me-me	B	T	me-me
January	I				21.8	19.1	2.56	12.0	8.0		9.8	7.6	2.1
	II							10.5	8.5		6.2	4.5	
	III							6.5	4.7				
February	I				21.3	9.7	2.3	11.8	9.9		10.6	7.7	1.7
	II				11.3	8.9		9.0	6.2		5.4	3.7	
	III							3.7	2.0		7.0	2.2	
March	I				7.7	3.0	1.6						
	II				14.4	6.4		5.7	6.4				
	III							1.9	0.7				
April	I				9.1	4.7	2.4	5.0	6.2				
	II				12.2	5.1		0.8	0.7				
	III												
May	I				8.5	6.2	2.4						
	II				11.9	5.8		3.8	3.1				
	III							0.5	0.45				
Jun	I				5.6	3.7	1.8						
	II				10.5	5.6		6.1	0.3				
	III							1.1	1.5				
July	I				5.3	3.7							
	II				7.8	7.1		5.1	9.9				
	III				2.5	2.3		2.2	2.7				
August	I				3.4	2.2							
	II				4.8	4.6		5.1	5.2				
	III				1.5	1.5		2.0	2.8				
September	I				7.6	6.6		6.6	11.0	0.4			
	II				6.8	5.8		5.8	7.7				
	III				2.6	2.6		1.9	3.0				
October	I				7.8	9.1		7.3	12.8	31			
	II				8.1	6.2		6.3	9.8				
	III				5.2	5.0		1.3	2.0				
November	I	24.7	22.1	3.0	12.7	9.5		10.6	15.1	3.0			
	II	16.3	15.3		9.7	8.0		8.9	8.3				
	III				8.0	6.6		1.3	0.5				
December	I	18.9	19.8	2.7	10.8	7.9		15.1	18.3	4.6			
	II	9.04	9.55	8.2	8.2	5.7		9.2	6.7				
	III							6.0	5.3				

B=benzene; T=toluene; me-me=methyl mercaptane; I, II and III=monitoring sites

standardised incidence rate was 231.1 in 100,000 inhabitants). During the same period in the municipality of Pančevo there were an average of 155.9 new female cancer patients *per* year (the crude incidence rate was 245.0 and the standardised incidence rate was 141.2 in 100,000 inhabitants) (Table 3). The difference between central Serbia and Pančevo cancer incidence was statistically significant ($p<0.01$).

In male patients in both Pančevo and central Serbia lung and bronchal cancers predominated, followed by colon and rectal cancer. There are slight differences between the two populations when stomach, prostate and bladder cancers are considered. However, in both populations such types of cancer are ranked 3–5. When standardised incidence rates are compared it is clear that, apart from Hodgkin's disease, all standardised incidence rates are lower in Pančevo. It is also important to note that in Pančevo the standardised incidence rate for »Other and unspecified cancers« was unusually high (Table 2).

In females breast cancer predominated in both Pančevo and central Serbia. Slight differences in the rankings of colon and rectal, cervix uteri and lung and bronchal cancers (ranking range 2–5) were evident between the two populations. As was the case for males, the standardised incidence rate in Pančevo was lower for almost all types of cancer (except for brain and gallbladder)

TABLE 2
AVERAGE NUMBER OF NEW MALE CANCER CASES AND CANCER INCIDENCE RATES ACCORDING TO PRIMARY CANCER SITE LOCALISATION (ICD10) IN PANČEVO AND CENTRAL SERBIA DURING THE PERIOD 2003–2008

Primary sites (ICD10)	Pančevo				Central Serbia			
	Number of new cancer cases	Cancer incidence rates*	Cancer standardised incidence rates**	Rank	Number of new cancer cases	Cancer incidence rates*	Cancer standardised incidence rates**	Rank
Lung and bronchus (C34)$^{++}$	30.1	48.9	30.4	1	2758.9	105.1	61.1	1
Colon and rectum (C18-C20)$^{++}$	21.5	34.7	20.3	2	1630.3	61.7	34.1	2
Prostate (C61)$^{++}$	10.7	17.4	10.0	4	1239.4	47.0	22.5	3
Bladder (C67)$^{++}$	11.2	18.1	10.9	3	820.2	31.1	16.7	4
Stomach (C16)$^{++}$	5.7	8.8	6.1	5	622.5	23.5	13.1	5
Larynx (C32)$^{++}$	3.2	2.8	2.1	15	521.7	19.8	11.9	6
Brain (C71)$^{++}$	2.8	4.6	3.2	10	365.7	12.9	10.6	7
Leukaemias(C91-95)$^{++}$	3.0	4.9	3.7	9	272.5	10.4	7.3	8
Mouth and pharynx (C00-C10)$^{++}$	2.3	3.8	2.8	14	301.8	11.5	6.8	9
Pancreas (C25)	3.9	6.2	4.0	7	297.5	11.5	6.5	10
Kidney. except renal pelvis (C64)$^{++}$	3.4	5.8	3.7	8	280.0	10.6	6.4	11
Testis (C62)$^{++}$	1.2	2.0	1.5	16	155.0	6.1	5.7	12
Liver & intrahepatic bile ducts (C22)$^{+}$	3.3	5.5	2.9	12	264.2	10.1	5.6	13
non-Hodgkin's disease (C82-85)	4.2	6.4	4.3	6	212.2	8.1	4.7	14
Malignant melanoma of skin (C43)	2.5	4.1	2.9	13	176.8	6.6	4.3	15
Oesophagus (C15)$^{++}$	1.2	2.0	1.3	17	137.7	5.2	3.1	16
Hodgkin's disease (C81)	2.3	3.7	3.1	11	84.0	3.2	2.5	17
Other and unspecified $^{++}$	103.7	181.5	105.3	–	1280.8	40.7	19.1	–
All sites (C00-C96) but skin (C44)$^{++}$	216.2	361.2	218.3	–	11421.0	425.1	241.7	–

* *per* 100.000 population; ** *per* World population *per* 100.000; $^{+}$ $p<0.05$; $^{++}$ $p<0.01$

compared with the standardised incidence rate in central Serbia (Table 3).

Discussion

Research activities concerning the impact of local industrial pollution on public health are complex tasks due to the existence of several variables including: exposure estimation accuracy, definition of the study population, diagnostic validation of new cancer patients and expectations of the local community.

In our current study exposure to pollution was assessed by analysing data collected by automatic sampling and monitoring at three stationary sites.

The average yearly production at the Pančevo petrochemical facility is 300,000 tons *per* year during the period from 2004–2006. A number of products including pyrolytic gasoline, pyrolytic oil, C4 fraction, propylene and ethylene are manufactured. During the period 2004–2006 an average of 4.8 million tons of oil was refined *per* year in the oil refinery[10].

During several years air quality measurement data in the municipality of Pančevo were either not available or were incomplete. The local authorities started systematic air quality monitoring from 2004. In addition to analysing SO_2, NH_3 NO, CO, O_3 and PM (10) special attention was focused on monitoring benzene, toluene and methyl mercaptane, agents known to affect public health. The systematic local monitoring of benzene, toluene and methyl mercaptane in the atmosphere within the Pančevo industrial area revealed that the average concentration (on a monthly and *per* year basis) exceeded (with frequent peaks as high as 160.5 μgm^{-3}) permitted levels proposed by the EU.

TABLE 3
AVERAGE NUMBER OF NEW FEMALE CANCER CASES AND CANCER INCIDENCE RATES ACCORDING TO PRIMARY CANCER SITE LOCALISATION (ICD10) IN PANČEVO AND CENTRAL SERBIA DURING THE PERIOD 2003–2008

Primary sites (ICD10)	Pančevo				Central Serbia			
	Number of new cancer cases	Cancer incidence rates*	Cancer standardised incidence rates**	Rank	Number of new cancer cases	Cancer incidence rates*	Cancer standardised incidence rates**	Rank
Breast (C50)$^{++}$	31.1	48.2	29.7	1	2772.5	99.7	59.3	1
Cervix uteri (C53)$^{++}$	17.4	26.8	14.3	3	978.3	35.3	24.1	2
Colon and rectum (C18-C20)$^{++}$	18.9	30.5	18.7	2	1158.3	41.5	20.5	3
Lung and bronchus (C34)$^{++}$	11.1	20.0	13.5	4	867.0	31.4	16.6	4
Corpus uteri (C54)$^{++}$	8.2	12.9	8.1	5	642.2	24.1	13.2	5
Ovary (C56)$^{++}$	3.2	4.8	3.3	9	461.2	16.6	10.1	6
Stomach (C16)$^{++}$	2.0	3.1	2.0	14	390.2	14.1	6.9	7
Brain (C71)	6.7	9.9	7.0	6	262.4	9.4	6.7	8
Bladder (C67)$^{++}$	3.1	4.8	3.0	11	277.7	9.8	4.8	9
Leukaemias (C91-85)	3.1	5.0	3.4	7	192.5	6.9	4.7	10
Pancreas (C25)$^{++}$	1.8	2.9	1.5	15	242.0	8.75	4.1	11
non-Hodgkin's disease (C82-85)	2.8	4.3	3.4	8	168.6	6.1	3.7	12
Kidney. excpect renal pelvis (C64)	3.8	5.9	3.1	10	177.8	6.4	3.5	13
Liver & intrahepatic bile ducts (C22)$^{+}$	2.7	4.1	2.2	13	190.8	7.0	3.2	14
Mouth and pharynx (C00-C10)$^{++}$	1.0	1.5	1.1	17	132.3	4.9	2.8	15
Hodgkin's disease (C81)	1.4	2.4	1.3	16	73.8	2.7	2.3	16
Gallbladder (C23)	2.1	3.2	2.5	12	87.8	3.2	1.5	17
Other and unspecified^{++}	35.5	55.0	23.3	–	2182.5	77.0	43.2	–
All sites (C00-C96) but skin (C44)$^{++}$	155.9	245.0	141.2	–	11257.9	404.6	231.1	–

* *per* 100.000 population; ** *per* World population *per* 100.000; $^{+}$ $p<0.05$; $^{++}$ $p<0.01$

The effect of exposure of benzene, toluene and mercaptane on public health and the appearance of various diseases have been documented[11–19]. Exposure to high concentrations of benzene induces chromosomal aberrations and cytogenetic damage[11,12]. Ontogenetic alterations in molecular structures have been found after exposure to polychlorinated biphenyls[13]. Benzene, toluene and xylenes present in petrol can penetrate through human abdominal skin producing systemic effects[14] and aromatic fuel hydrocarbons and methyl substituted benzenes can cause skin diseases[15,16]. Benzene is classified as a potent carcinogen and has been implicated in the pathogenesis of lymphohematopoetic malignancies[17,18] and in leukemia[19].

Analysis of data collected from Cornigliano[20] (a district in Genoa, Italy) revealed a higher risk of lung cancer incidence in females living in the vicinity of a coke oven installation. In some industrial regions of Sardinia (Portoscuso, Sarroch and Porto Torres) a higher incidence of respiratory diseases (including cancers) has been reported[21].

According to our data the incidence of cancer in Pančevo was not higher than in the region of central Serbia. The latter lacks petrochemical and oil refining activities and is free from such air pollution. Nevertheless, the standardised cancer incidence of all types of cancer predominates in central Serbia. These results were unexpected and surprising, especially when taking into consideration the high atmospheric concentrations of benzene, toluene and methyl mercaptane and their proven harmful effects. In the literature there are studies considering similar scenarios to ours, such as the one conducted in Teeside[22]. Living near a constellation of petrochemical, steel and other industries did not exhibit elevated specific morbidity. Furthermore, the results of study performed in California (USA)[23] indicated that environmental exposure to petrochemical fumes in the San

Francisco Bay area were not associated with increased cancer occurrence.

In contrast, a number of studies have demonstrated harmful health effects caused by industrial pollutants and the association of industrial pollution with adverse health. The Harvard Six Cities Study indicated association of ambient PM (2.5) concentrations with total, cardiovascular and lung cancer mortality[24]. In another study[25] increased lung cancer mortality was noted in women living in the vicinity of industrial centres in Northeast England, which could not be attributed to smoking, occupations, socioeconomic factors or artefacts. In Teeside lung cancer risk was moderately increased in a population residing close to an area containing heavy industry[2]. An increase in the number of deaths caused by bone, brain and bladder cancer in children and adolescents (up to 19 years old) living in the proximity of three petroleum and petrochemical plants was reported in Kaohsiung (Taiwan)[26].

As there is no clear or meaningful explanation for the results of our study, one could question the reliability of Serbian cancer patient data collection particularly from the start of the 1990s. However, it appears that our results are not biased by such a problem because a study by Vlajinac and colleagues[27] clearly demonstrated that the Cancer Register in Belgrade and in Vojvodina were reliable to estimate cancer incidence in Serbia. Moreover, taking into account that the authorities in Vojvodina (northern part of Serbia were Pančevo is situated) are known for their good record keeping one might have expected the opposite conclusion from our study (that cancer incidence in Pančevo is higher than in central Serbia).

Conclusion

By excluding the possibility that our results were jeopardized by unreliable cancer patient collection data, we can conclude that the available data do not allow us to correlate air pollution in Pančevo with increased cancer incidence.

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STOPA OBOLJENJA OD RAKA KOD POPULACIJA KOJE ŽIVE BLIZU PETROKEMIJSKIH OBJEKATA I RAFINERIJA NAFTE

S A Ž E T A K

Sve se više izražava zabrinutost i sumnja da zagađenje zraka od strane petrokemijskih objekata i instalacija rafinerije nafte u Pančevu (Srbija) dovodi do povećane stope oboljenja od raznih bolesti, uključujući i rak. Cilj ovog istraživanja bio je utvrditi stopu oboljelih od raka u Pančevu i usporediti ju sa stopom oboljelih u središnjoj Srbiji. Podaci o učestalosti oboljenja od raka prikupljeni su iz srpskog Registra za rak. Sistematsko lokalno praćenje udjela benzena, toluena i metil-merkaptana u atmosferi pančevske industrijske regije ukazalo je na činjenicu da prosječne mjesečne i godišnje koncentracije navedenih spojeva često prelaze granične vrijednosti propisane od strane Europske unije (5 μgm^{-3}). Ustanovljeno je da je stopa oboljenja od raka niža u Pančevu nego u središnjoj Srbiji (standardizirana stopa za oboljenje od svih tipova raka je u Pančevu iznosila 218,3, a u središnjoj Srbiji 241,7 na 100 000 stanovnika). Dobiveni rezultati nam dakle ne dopuštaju da dovedemo u vezu zagađenje zraka u Pančevu i povećanu stopu oboljenja od raka.