Arsenic Contamination of the Coastal Aquifers in the North Coast of Java, Indonesia

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Abstrak

Pesatnya perkembangan industri dan aktivitas domestik di daerah pantai utara Jawa mendorong perlunya dilakukan penelitian tentang kemungkinan adanya pencemaran logam Arsen (As) di akifer dangkal kota-kota Jakarta, Semarang dan Surabaya. Tiga puluh contoh air dari sumur-sumur yang berasal dari zona pemukiman di daerah pesisir dianalisis kandungan logam As dengan menggunakan teknik Atomic Absorption Spectrophotometer. *Hasil analisis menunjukkan rata rata kandungan logam As di Jakarta, Semarang and Surabaya adalah 15,19 ± 18,79; 1,25 ± 2,05 and 0.59 ± 0.26 µgL^{-1}. Terdapat korelasi yang nyata antara logam As dengan Fe di airtanah. Tingkat kandungan logam As di daerah akifer pantai utara Jawa masih berada di bawah ambang yang dipersyaratkan oleh* Indonesian Drinking & Domestic Water Quality Standard for Ground Water and WHO's (World Health Organization) Guideline Values for Drinking Water, *kecuali untuk stasion 6 dari Jakarta dengan konsentrasi 59,65 µgL^{-1}.*

Kata kunci : *Arsen (As), kontaminasi, akifer pantai.*

Abstract

A study was conducted to assess the Arsenic (As) metal contamination of the shallow aquifers in Jakarta, Semarang, and Surabaya city of Java and its relation to the highly developed industrial and domestic activities in the coastal region. Arsen was assayed in the waters of 30 wheals throughout the terrestrial cities, in residential zones using Atomic Absorption Spectrophotometer technique. The mean and standard deviation of As in Jakarta, Semarang and Surabaya were 17.19± 19.08, 1.78 ± 2.28 and 0.59 ± 0.26 µgL^{-1}, respectively. The r As concentration of groundwate shows in correlation with Fe significantly. The levels of As in some investigated three Indonesian metropolis cities were below the maximum allowable concentrations of metals recommended by Indonesian Drinking & Domestic Water Quality Standard for Ground Water and WHO's (World Health Organization)*Guideline Values for Drinking Wate, except for station 6 of Jakarta were concentration 59,65 µgL^{-1}.*

Key words: *Arsenic (As), contamination, coastal aquifer*

Introduction

Arsenic (As) is one of the most important toxicant that are widely distributed in nature and occur in the form of inorganic and organic compounds. Exposure to inorganic compounds may occur in variety ways through certain industrial effluents, chemical alloys, pesticides, wood preservative agents, combustion of fossil fuels, catalysts, glass, fire retardant, occupational hazards in mining that are anthropogenic sources and natural sources (Smedly & Kinniburgh, 2002).

Arsenic is known to cause arsenicosis due to its manifestation in drinking water, the most common species being arsenate As (V) and arsenite As (III) (WHO, 2007). Arsenic contamination of groundwater has led to a massive epidemic of arsenic poisoning in Bangladesh (Anawar *et al.*, 2003; Chowdhury, 2004) and neighbouring countries (Berg *et al.*, 2001; Nickson *et al.*, 2005). It is estimated that approximately 57 million people in Bangladesh (Yu *et al.*, 2003) and 11 million people in Vietnam (Berg *et al.*, 2001) are drinking groundwater with arsenic concentrations elevated above the World Health Organization's standard of 10 parts per billion (WHO, 1993). This tragedy was occurring as the high arsenic levels present in drinking water. Bangladesh maintains an allowable limit of 50 mgL^{-1}, and the limit in Canada is 25 mgL^{-1} (Nordstrom, 2002). The arsenic found in

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Bengale and Canada drinking water is present naturally in the sediment but is released only by humans, primarily from the digging of shallow wells. Similarly unacceptably high arsenic levels are found in shallow-well domestic drinking water in the American Midwest (Kim *et al.*, 2002). Recently there has been increasing anxieties concerning arsenic related problems. Occurrence of arsenic contamination has been reported worldwide, for example, Mongolia (Gong *et al.*, 2006), USA (Welch *et al.*, 2000; Kim *et al.*, 2002; Hudak, 2008;), Bangladesh (Anawar *et al.*, 2003; Chowdhury, 2004), Taiwan (Chen *et al.*, 1994), and Spain (García-Sánchez *et al.*, 2005). In Indonesia, no significant As contamination has been reported yet. However, local contaminations in soils, sea and groundwaters with high As and Hg levels have been frequently revealed particularly around Buyat Bay mining areas (Khalik & Wulandari, 2004; KLH, 2004).

Most of the water requirement for metropolis city such as Jakarta, Semarang, Surabaya, is from surface and groundwater supplies piped in from outside the city limits. However, the case for many cities, a certain proportion of the population, usually the poorest, is forced to rely on dug and shallow wells within the urban area. A study was therefore carried out to gain an idea of the inorganic quality of the water in the wells penetrating the shallow aquifer below the city. This research aim to examine the As content of shallow aquifer in coastal urban areas of Jakarta, Semarang and Surabaya and assess how far they conform with the WHO/Indonesia recommendations for drinking water.

Material and Methods

Water collections

A total of thirty samples were collected at each of the stations. Water samples used for As analyses were collected from the residential area shallow aquifer of the north shore of Jakarta, Semarang, and Surabaya metropolis during July-August, 2007 (Fig.1). Shallow aquifer waters are the only sources for drinking water in the study area, however some people uses these waters directly for domestic purposes and drinking water, not through the water supplies system. The water samples were collected in 1000 mL plastic bottles. Then, bottles were properly labeled and tightly sealed. The water samples then were brought to the laboratory for performing water quality tests and heavy Arsenic analyses.

Arsenic metal analysis

The water samples were acidified with aliquot of HNO_3. About 100 mL each of the wellmixed acidified water was digested with 5 mL HCl. The digested samples were then analyzed for As using atomic absorption spectrometer Perkin Elmer Model 3000 (Kremling *at al*, 1998). A statistical analysis was conducted among the standard parameters using Linear correlation method. To know the relationship between concentration of As and Fe (the Fe sources data from Chrisna *et al.*, 2007) the parameters existed or not.

Statistical analysis

The value was used to analyze correlations between As and Fe. ANOVA analysis was made among locations of heavy metal content. All the statistical methods were done using the software Minitab ver.15. Analysis of variance ANOVA was employed after logarithmic conversion when necessary to detect significant differences among the means.

Result and Discussion

The appearance of arsenic in groundwater and drinking water is a worldwide concern since it has been found that arsenic is one of the most toxic and carcinogenic chemical elements. In the present study the mean and standard deviation of As in Jakarta, Semarang and Surabaya were 17.19±19.08, 1.78±2.28 and 0.59±0.26 mgL^{-1}, respectively. The maximum As concentration was observed in Jakarta (59.65 μgL^{-1}) on station 6 at Kamal area. Statistically, there were significant differences of As content among locations, Jakarta, Semarang and Surabaya. Both Semarang and Surabaya were no significant different on As (Table 1). This condition could be explained that arsenic can enter the water supply from natural deposits in the earth or from industrial and agricultural pollution. It is a natural element used for a variety of purposes within industry and agriculture. It is also a byproduct of copper smelting, mining, and coal burning (Anonymous, 2008). Industries in Jakarta were suspected release much more arsenic into the environment every year than those of Semarang and Surabaya. Once released, arsenic remains in the environment for a long time. However, in the present results of this study when it was compare to the previous results in Buyat Bay for Drinking Water (KLH, 2004), it was lower. Because it may be stated that the environmental parameters like salinity, temperature, dissolved oxygen and pH may have effect on the accumulation of trace metals. Among the parameters, the salinity play major role in the metal accumulation (Rajan, 1987). Figure 2 showed a positive and significant correlation between As and Fe in coastal aquifer of Java north shore. As consentrations is well correlate with concentration of dissolved Fe. It means

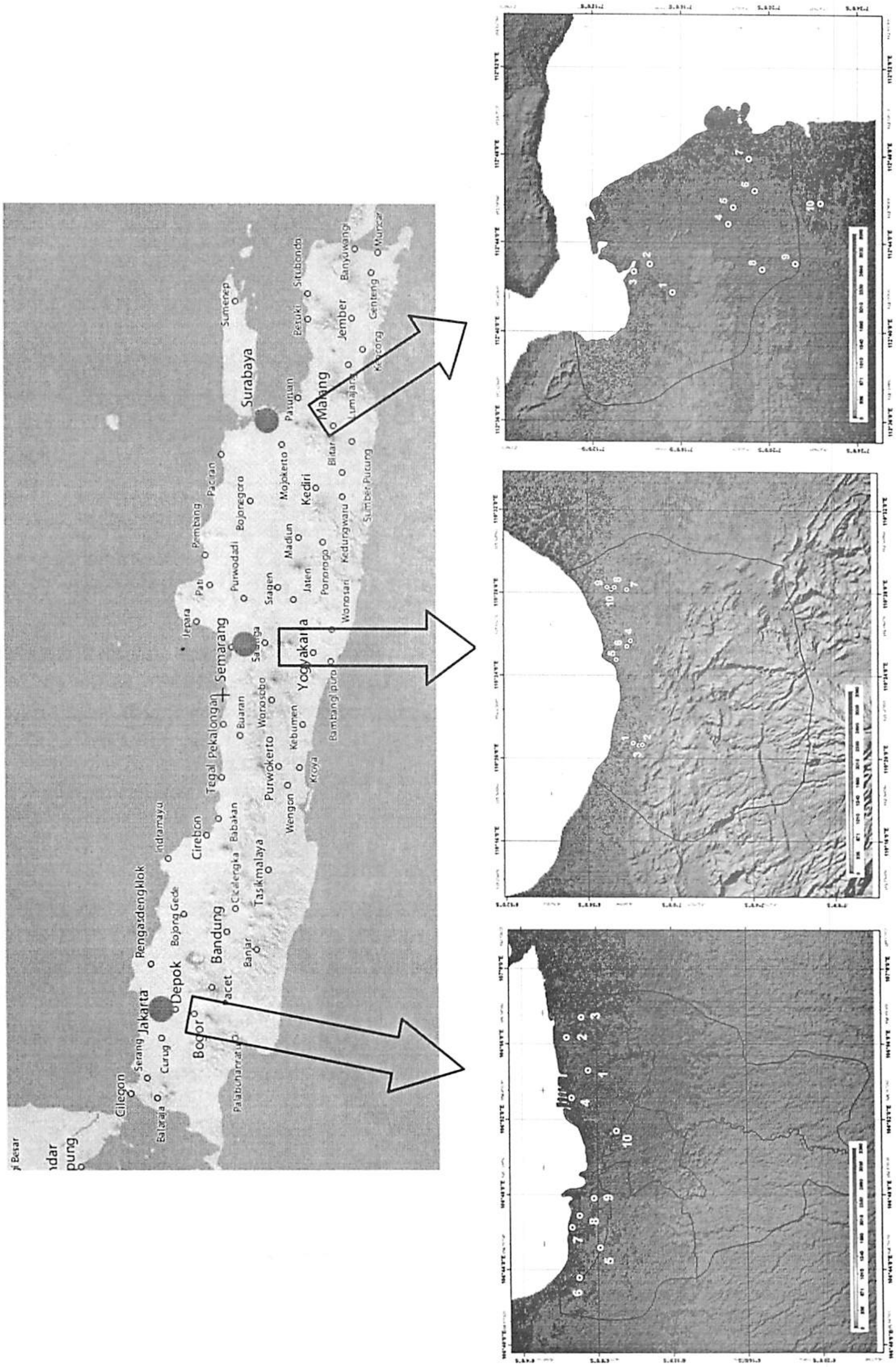

Figure 1. The map of sampling site locations

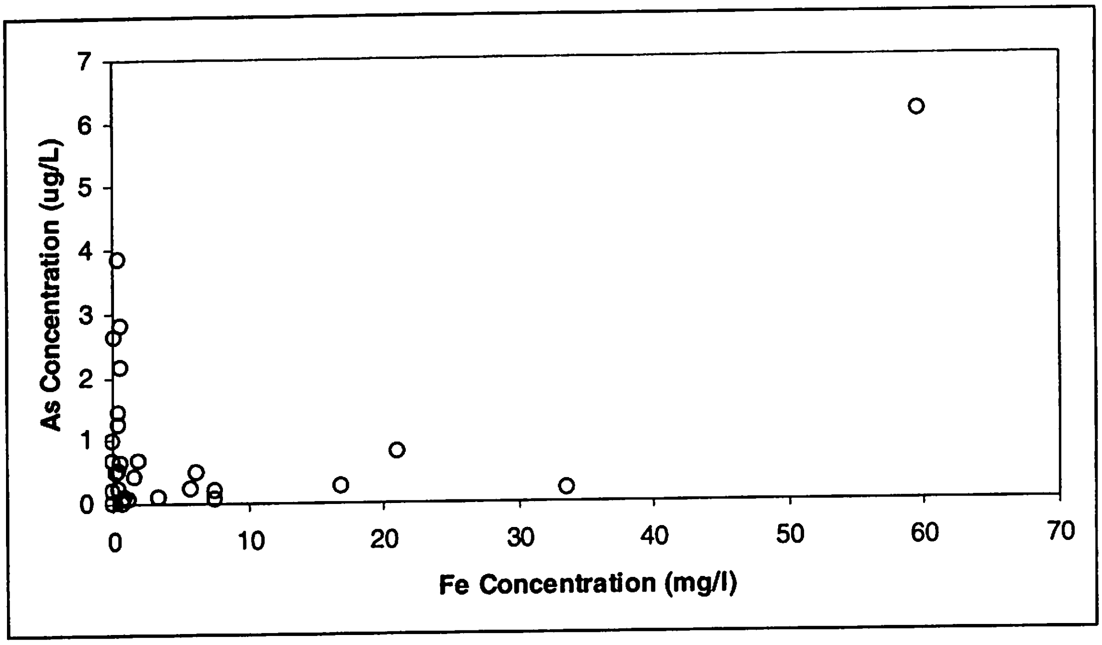

Figure 2. Relation of Arsenic and Iron in coastal aquifer (p=0.005)

Table 1. Range, mean and standard deviation of as content (µL-1) in coastal aquifer of Java north shore.

Sampling Station	As concentration (µgL⁻¹) in:		
	Jakarta	Semarang	Surabaya
ST1	7.5	0.54	0.25
ST2	33.65	0.13	0.39
ST3	5.76	<0.001	0.40
ST4	7.58	1.63	1.11
ST5	21.07	0.50	0.66
ST6	59.65	6.21	0.89
ST7	1.90	3.42	0.43
ST8	<0.001	0.03	0.51
ST9	16.9	<0.001	0.54
ST10	0.69	<0.001	0.76
Range	0-59.65	0-6.21	0.25-1.11
Mean and STDEV	15.47±18.79 a	1.25±2.05 b	0.59±0.26 b

Note: The difference of alphabet showed significant difference

that the higher the dissolved Fe, the higher arsenic concentration. Many authors have reported the correlations between As and Fe in a variety of environments, since As adsorbs onto Fe (hydroxides) under oxidizing conditions and is then released when the hydroxide undergoes reductive dissolution (Zheng *et al.*, 2004; Mirlean *et al.*, 2006). Bhatacharya *et al.* (1997) reported that arsenic is released when arsenic-rich iron oxyhydroxides are produced in anoxic groundwater. In addition, Nickson *et al.* (1998) stated that arsenic derived from the oxidation of arsenic-rich pyrite in the aquifer sediments as atmospheric oxygen invades the aquifer in response to a lowering of the water level by abstraction. Previous investigations in Bangladesh have also suggested that arsenic may enter the aquifer associated with iron oxide coatings on the sediment grains and when conditions become reduced, the arsenic is released to the groundwater together with Fe^{2+} (McArthur *et al.*, 2001; Smedly and Kinniburgh, 2002). Bone *et al.* (2006) reported that strong correlation between As and Fe provides solid evidence that As is linked to the Fe redox cycle.

Conclusion

This experiment has shown that the entire water sample meets the limits of WHO and Indonesian Drinking & Domestic Water Quality Standard for Ground Water, except for station 6 on Kamal area in Jakarta. This study confirmed a significant relationship between the arsenic and iron concentration in north coastal aquifer of Java. It means that coastal aquifer of Java north shore is not polluted. With regard to mitigation, shallow aquifer with low concentrations of arsenic need to be monitored regularly by related authorities to ensure arsenic concentrations in water remain at an acceptable level.

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