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Persistent Organochlorine Residues in Household Wells of Java Coastal Urban Areas, Indonesia

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Abstract: The present study was conducted to assess psycho-chemical parameters and the level of organochlorine contamination in household wells of coastal urban region, Java. Results indicated that low variation existed among some physico-chemical parameter (pH, temperature, salinity). In the water sample colour, taste and odor were investigated. Mean values found in positive samples were 0.10±0.10, 0.010±0.003, 0.455±0.30, 0.77±0.17 and 0.934±0.27 μg L^{-1} for heptachlor, aldrin, endosulfan, endrin and p,p-DDT, respectively. Comparison of the organochlorine contents in the water sample with World Health Organization (WHO) limits and Indonesian Drinking and Domestic Water Quality Standard for Ground Water (IWQS) showed that some of the household wells were contaminated with organochlorine. This study has proven the presence of organochlorine contamination of some household well supplies in the coastal urban area of Java. Their presence poses health risk to the inhabitants of coastal settlement consuming this water resource directly without treatment.

Key words: Physico-chemical, Jakarta, Semarang, Surabaya

INTRODUCTION

The use of pesticides, herbicides and fungicides in Indonesia began when the government launched plantation rehabilitation programme in the 1960's (Indonesian Pesticide Committee, 1999). Consequently, large-scale application of these toxic materials in agriculture areas can contribute to the presence of those compounds in surface and ground water, lakes, estuary and ultimately in the coastal areas. Most of these compounds are recalcitrant to biodegradation and their entry into the ground water, might be, poses many challenges to the existing of drinking well water from pollution.

Indonesian Pesticide Committee is responsible for the import permission for pesticides, when the government launched plantation rehabilitation programme. The 1974 official list of permitted pesticides contains 94 pesticides, which represent about 76 different compounds. Some of them are brought on the market under different trade names (Hadiwijaya, 1974). Excluded from the list are DDT, Endosulfan, Heptachlor, Aldrin, Dieldrin, Endrin and a number of other persistent chlorinated pesticides. Their use in plantation, aquaculture and agriculture is prohibited (Duursma, 1976). However, DDT is still allowed to be used for domestic and health purposes in particular for fighting the malaria mosquito. Dieldrin and Endrin were previously widely used and in some places old stocks are still available, thus creating the possibility that these pesticides might still be found in the environment (Chozanah, 2007; Watterson, 1999).

Java is by far the most populous island in Indonesia, with approximately 62% of the country's population and is the most populous island in the world (Calder, 2007). With 130 million inhabitants at 1026 people per km^2, it is also one of the most densely-populated parts of the world (BPS Statistics Indonesia, 2000; Anonymous, 2001). Jakarta (the capital and largest city of Indonesia), Semarang and Surabaya are located on the Northern coast of Java Island. Like many big cities in developing countries, these cities suffer from major urbanization problems. The cities are highly urbanized, due to the many industries located in the city and as a result, there is also a large slum area. Therefore, there is a require outstretching of existing housing and most importantly water supply. Alternative supply of water for domestic and industrial purposes has been diversified to the area of bore-hole and well drilling, stream and rain water collection and storage.

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Clean water is probably the biggest problem in many houses of coastal urban settlement. Based on field investigation, many homes in this region are not connected to the city water supply and wells are often unpredictable. Most houses do not have overhead tanks for catchment or storage but, instead, have large ground storage tanks from which the water is pumped on demand by a small electric pump. The most prevalent of these is the shallow aquifer (dug well) which has become the major source of water in the coastal inhabitants. However, ground waters and surface waters are never pure that probably contain a variety of organic compounds (Fitch and Du, 1996; Nelson *et al*., 1998; Graber *et al*., 2001). Organic chemicals such as polychlorinated biphenyls, PAHs and organochlorine pesticides have been identified in the surface water (Jaynes *et al*., 1999; Louchart *et al*., 2001; Rupp *et al*., 2006) and ground water (Muszkat *et al*., 1993; Barbash *et al*., 2001; Lapworth *et al*., 2006). Contaminants from residential areas, industries and agricultural practices through migration and infiltration enter to ground waters (Ilani *et al*., 2005; Yusuf, 2007). Therefore, a study of the distribution and concentration of organochlorine in the shallow aquifer become the most relevant. This research aims to examine the organochlorine content of the household wells in coastal urban areas and assess how far they conform to the WHO/Indonesia recommendation for drinking water.

MATERIALS AND METHODS

Water sample collection: Sampling points were located on coastal urban areas flowing from the west to the east of Java, namely Jakarta, Semarang and Surabaya. Figure 1 shows the sampling sites. Well water samples were collected in polyethylene plastic bottles from 30 different dug wells across those cities during the months of July to August 2007. The water samples were collected in 1000 mL plastic bottles. Then, bottles were properly labeled and tightly sealed. All the water samples were brought to the laboratory for performing organochlorine analyses. The parameters analyzed were psycho-hydrochemical properties and organochlorine contents of shallow ground water. The pH, salinity and temperature were measured at the time of samples collection using pH meter, hand refracto salino meter and a standard centigrade thermometer (Horiba Co. Ltd., Japan).

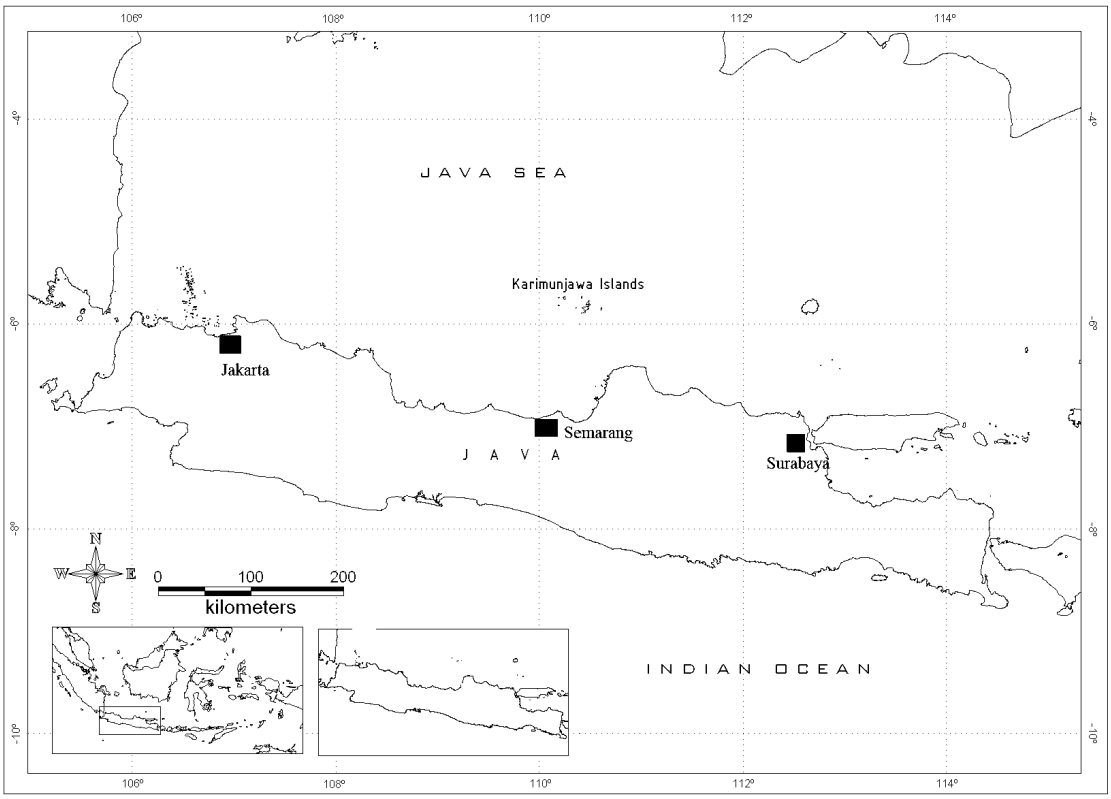

Fig. 1: The map of sampling site locations

Sample analysis: The analytical procedure applied was the method of the Standard Method for the Examination of Water and Waste Water (American Public Health Association, 1992), using 15% methylene chloride in n-hexane and capillary columns. One-liter samples were extracted with a solvent mixture and then concentrated in a Kuderna-Danish apparatus. The extracts were cleaned up with Florisil column. The final pesticide extract was obtained in 5 mL of hexane. The samples were then analyzed by gas chromatograph Model Hitachi 163 FPD (Flame Photometer Detector) and nitrogen High Pure (HP) was used as the carrier gas. A 2 m glass column (3 mm ID) packed with 3% Silikon OV1 on 80-100 mesh Supelcon was used. Gasflow at 30 mL min^{-1}, column temperature at 160-230°C, detector temperature at 290°C and the injector temperature at 290°C were maintained.

RESULTS AND DISCUSSION

Java is an island which administratively divided into four provinces (Banten, West Java, Central Java and East Java), one special region (Yogyakarta) and one special capital district (Jakarta). Jakarta, Semarang and Surabaya are the capital city of Indonesia and Jakarta special district, Central Java and East Java, respectively. These cities were chosen for study because of their representative for the main industrial and human centre of northern coastal urban of Java. Hence, those cities have a great probability for the existence of declining water quality resources.

Pollution of groundwater has been reported for a number of urban throughout the world on a wide range of pollutants, such as organochlorine, heavy metals, nitrate, fecal, bacteria, virus, domestic waste (Mille *et al*., 1993; Somasundaram *et al*., 1993; Zhang *et al*., 1996; Kaçaroğlu and Günay, 1997; Mazari-Hiriart *et al*., 1999; Reddy and Dunn, 1997; Howard *et al*., 2003; Timothy *et al*., 1999; Chrisna *et al*., 2007; Sabdono *et al*., 2007). This is mainly due to a higher population density and more intensified agricultural and industrial activities (Baudino *et al*., 2003; Yusuf, 2007; Fatoki and Awofolu, 2004; Mukherjee and Gopal, 2002). In present study, the results of some physicochemical parameters and selected priority organochlorine in shallow aquifer are preserved in Table 1 and 2, respectively. This study indicated that low variation existed among some physico-chemical parameter

Table 1: Physico-chemical properties of the well water samples in the Java coastal urban area

		Physico-chemical parameters					
City	Sampling site No.	Colour	Odor	Taste	pH	Salinity	Temp. (°C)
Jakarta	SGW1	Colourless	Odourless	Tasteless	7.0	0.0	28.5
	SGW2	Colourless	Odourless	Tasteless	7.0	0.0	28.5
	SGW3	Colourless	Odourless	Salty	6.5	7.0	29.0
	SGW4	Colourless	Odourless	Tasteless	7.0	0.0	29.0
	SGW5	Greyish	High offensive	Tasteless	7.0	0.0	29.5
	SGW6	Colourless	Odourless	Tasteless	7.0	3.0	29.5
	SGW7	Colourless	Odourless	Tasteless	7.0	4.0	29.0
	SGW8	Colourless	Odourless	Tasteless	7.0	0.0	29.0
	SGW9	Colourless	Odourless	Tasteless	7.0	2.0	29.0
	SGW10	Brownish	Offensive	Tasteless	7.0	1.0	29.0
Semarang	SGW11	Brown	Offensive	Tasteless	6.5	2.0	29.0
	SGW12	Bluish	Odourless	Tasteless	7.0	2.0	29.0
	SGW13	Colourless	Odourless	Tasteless	7.0	0.0	29.0
	SGW14	Colourless	Odourless	Tasteless	7.0	0.0	29.0
	SGW15	Greyish	Offensive	Tasteless	7.0	2.0	29.0
	SGW16	Colourless	Odourless	Tasteless	7.0	2.0	29.0
	SGW17	Colourless	Odourless	Tasteless	7.0	0.0	29.0
	SGW18	Colourless	Offensive	Tasteless	7.0	5.0	29.0
	SGW19	Colourless	Offensive	Salty	7.0	7.0	29.0
	SGW20	Colourless	Offensive	Salty	7.0	9.0	29.0
Surabaya	SGW21	Colourless	Odourless	Tasteless	7.0	5.0	28.5
	SGW22	Colourless	Odourless	Tasteless	7.0	5.0	29.0
	SGW23	Colourless	Odourless	Tasteless	7.0	0.0	28.5
	SGW24	Colourless	Odourless	Tasteless	7.0	0.0	29.0
	SGW25	Colourless	Odourless	Tasteless	7.0	0.0	29.0
	SGW26	Colourless	Odourless	Tasteless	7.0	2.0	29.0
	SGW27	Colourless	Odourless	Tasteless	7.0	3.0	28.5
	SGW28	Colourless	Odourless	Tasteless	7.0	1.0	29.0
	SGW29	Colourless	Odourless	Tasteless	7.0	0.0	29.0
	SGW30	Colourless	Odourless	Tasteless	7.0	1.0	28.5
Range					6.5-7.0	0.0-9	28.5-29
Mean±SD					6.97±0.13	2.1±2.51	28.93±0.25
WHO/Indonesia	15 Pt-Co	Odourless	Tasteless	6.50-8.00			

Table 2: Range, frequency of occurrence and mean±standard deviation of organochlorine pesticide residue levels (μg L^{-1}) from Java coastal urban areas

City	Sampling site No.	Organochlorine (μg L^{-1}) Heptachlor	Aldrin	Endosulfan	Endrin	p,p-DDT
Jakarta	SGW1	0.188	0.013	nd	nd	nd
	SGW2	0.067	nd	nd	nd	nd
	SGW3	0.153	nd	0.109	nd	nd
	SGW4	0.063	nd	nd	nd	nd
	SGW5	nd	nd	nd	nd	nd
	SGW6	0.079	nd	nd	nd	nd
	SGW7	0.293	nd	0.596	nd	0.724
	SGW8	0.346	nd	0.66	nd	0.844
	SGW9	0.06	nd	nd	nd	nd
	SGW10	0.118	nd	nd	nd	nd
Semarang	SGW11	0.038	nd	nd	nd	nd
	SGW12	nd	nd	nd	nd	nd
	SGW13	0.058	nd	nd	nd	nd
	SGW14	0.041	nd	nd	nd	nd
	SGW15	nd	nd	nd	nd	nd
	SGW16	0.025	nd	nd	nd	nd
	SGW17	nd	nd	nd	nd	nd
	SGW18	nd	nd	nd	nd	nd
	SGW19	0.023	nd	nd	nd	nd
	SGW20	0.027	nd	nd	0.648	nd
Surabaya	SGW21	0.038	nd	nd	nd	nd
	SGW22	nd	nd	nd	nd	nd
	SGW23	nd	nd	nd	nd	nd
	SGW24	nd	nd	nd	nd	nd
	SGW25	nd	0.007	nd	nd	nd
	SGW26	nd	0.009	nd	0.895	1.235
	SGW27	0.01	nd	nd	nd	nd
	SGW28	nd	nd	nd	nd	nd
	SGW29	nd	nd	nd	nd	nd
	SGW30	nd	nd	nd	nd	nd
% of detection		56.66	10.0	10.0	6.66	10.0
Range		0.01-0.346	0.007-0.013	0.109-0.66	0.648-0.895	0.724-1.235
Mean±SD		0.10±0.10	0.010±0.003	0.455±0.30	0.77±0.17	0.934±0.27
WHO/Indonesia		0.03/0.03	0.03/0.03	-	0.6	2.00/2.00

nd = not detected

(temperature, salinity, pH). Colour, taste and odors were detected in water samples. Some of the water samples, particularly some Jakarta and Semarang water samples, did not comply with the standard limits for drinking. The water samples have colour and offensive odour. The water temperature values obtained in this study varied slightly ranged from 28.5-29.5°C with a mean of 28.93°C. This is the most common water temperature in tropical zone. This temperature range of water samples is supposed to be affected by the intensity of the sunlight as temperature rose from 28.5-29.5°C on relatively hot day afternoon. Some workers reported that the temperature of water from tropical climate was little affected by seasonal variations of temperature (Efe *et al*., 2005; Ravindra *et al*., 2003). Salinity range was varied from 0 to 9.0‰ with a mean of 2.1±2.51‰. The highest desirable level for pH (7.0) is within the range of 6.5-8.0 values for drinking purposes (WHO, 1993).

Water samples from coastal urban areas of Java showed the presence of selected organochlorine (Table 2). Seventeen out of 30 samples (56.66%) contained residues of heptachlor, ranging from 0.01 to 0.346 μg L^{-1}, whereas aldrin ranging from 0.007 to 0.013 μg L^{-1} was detected in 3 samples (10%). Three samples (10%) showed residues of endosulfan and p,p-DDT and only two samples (6.66%) were found to contain residues of endrin. The ranging of endosulfan, endrin and p,p-DDT was 0.109 to 0.66, 0.648-0.895 and 0.724-1.235 μg L^{-1}, respectively. Mean values found in positive samples were 0.10±0.10, 0.010±0.003, 0.455±0.30, 0.77±0.17 and 0.934±0.27 μg L^{-1} for heptachlor, aldrin, endosulfan, endrin and p,p-DDT, respectively. Comparison of the organochlorine contents in the water sample with World Health Organization (WHO) limits and Indonesian Drinking and Domestic Water Quality Standard for Ground Water showed that some of the household wells were contaminated with organochlorine.

The mean levels of heptachlor and endrin were exceeded the maximum permissible levels for drinking water. However, both aldrin and p,p-DDT were below the maximum allowable concentrations. WHO International Standards for Drinking-water did not refer to endosulfan. Variation in residual levels in these samples could be due to location of the sampling.

Table 3: Mean±SD and frequency of occurrence of organochlorine pesticide residue levels (μg L^{-1}) in household well of Surabaya, Semarang and Jakarta

	Sampling site		
Organochlorine	Jakarta	Semarang	Surabaya
Heptachlor	0.152±0.105	0.035±0.001	0.017±0.0099
	9/10	6/10	2/10
Aldrin	0.013	BD	0.008±0.001
	9/10	-	2/10
Endosulfan	0.455-0.301	BD	0.103
	3/10	-	1/10
Endrin	BD	0.648	0.895
	-	1/10	1/10
pp-DDT	0.784±0.085	BD	1.235
	2/10	-	1/10

Note: Mean was calculated for positive samples. Total samples = 10. BD = below detection

The present study sufficiently shows the presence of organochlorine residues in most of the samples. Comparison of data on organochlorine residues of Jakarta, Semarang and Surabaya water samples showed that the highest levels and frequency of occurrence of heptachlor was Jakarta well water (Table 3). Although we have not analysed surface water samples for organochlorine residues in the present investigation, comparing the results reported here with other regional studies on river and sea water contamination (Ratnaningsih *et al*., 2000), different contamination levels with heptachlor and p,p- DDT were found. Heptachlor was not detected and the mean level of p,p-DDT was lower. It is not known whether this is due to irresponsible insecticide handling practice or groundwater transport processes.

CONCLUSION

Characteristics of selected physico-chemical parameters and organochlorine pesticide residues in household wells of Java coastal urban areas has been determined in this study. Heptachlor and Endrin only were above the maximum permissible value recommended by WHO and Indonesian Water Quality Standard. As expected, Jakarta coastal urban area was the most contaminated one because of the higher population density and the larger industrial sites. Some of these household wells needs further purification to ensure their sustainability for consumption of coastal urban inhabitants. It is necessary to study further in these areas during the wet and dry period due to fully evaluate the organochlorine impact of pollution on shallow groundwater in seasonal variation.

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