Int. J. Environ. Res., 3(3):403-410, Summer 2009
ISSN: 1735-6865

Early study of Surfactants in Indoor Dust and Their Connection With Street Dust

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Received 15 April 2008; Revised 20 Dec. 2008; Accepted 25 March 2009

ABSTRACT: As surfactants enhance the membrane transport of organic compounds, it has to be assumed that they decisively influence the absorption of pollutants from house dust. Sampling sites for the surfactant analysis include housing areas, each location of which has different surroundings such as rural, urban, construction, and industrial area. Three stations had been selected for each housing area and cooking and smoking activities were recorded for each house. The concentration of anionic and cationic surfactants was determined as Methylene Blue Active Substances (MBAS) and Disulphine Blue Active Substances (DBAS) methods each using an ultraviolet-visible spectrophotometer. The results indicated that the concentrations of MBAS and DBAS in indoor dust were much higher than the street dust. It is concluded that activities in the house itself contributed significantly to the high concentration level of MBAS and DBAS in indoor dust. Overall, the sequence of concentration level of anions is as follows, $Cl^- > NO_3^- > SO_4^{2-}$. The correlation between MBAS with all the anions are weak ($R^2_{chloride} = 0.0072$, $R^2_{nitrate} = 0.2469$, $R^2_{sulphate} = 0.00004$) signifying that there is only a little connection between surfactants and these anions.

Key words: Surfactants, Indoor Dust, Street Dust, MBAS, DBAS, Indoor Pollution

INTRODUCTION

Surfactant (from the phrase surface-active agent) is a compound that will adsorb on the surface of air-water or oil-water and on solid. It is ampiphatic, i.e. it has two groups in a molecule; one of them has the affinity towards solvent whereas the other behaves antipathetic towards it (Attwood & Florence, 1983). The group structures that have a strong attraction to solvent are better known as liophilic group and so the liophobic group is drawn towards solvent (Rosen, 1988; Myers, 1999). Surfactant molecules strive towards the droplet surface due to their hydrophobic tail. This will lead to a situation where the surfactant density increases from droplet interior (bulk) towards the droplet surface causing a density maximum at a certain distance after which the density then decreases until the gas phase is reached (Sorjamaa and Laaksonen, 2006). Synthetic surfactants (detergent) are the main component in most cleaning agents.Cationic surfactants are mainly used in fabric softeners and for disinfection, whereas anionics and niosurfactants are the active ingredients in nearly all laundry detergents and cleansing agents for private and industrial purposes (Butte *et al.*, 2004). Most surfactants are in anionic form are the majority of cleaning detergents used in Asian countries (Thailand, Malaysia, Taiwan, Korea and Japan) containing 18-35% of anionic surfactants (Akira, 1990). In addition, anionic surfactants are also used widely is care products, textiles, paint, polymer, pesticide formulation, pharmaceuticals, mining and pulp and paper industries (Ying, 2006). Surfactants in suspended particulate matter can affect human health (Dye *et al.*, 2001; Cserháti

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et al., 2002; Hohr *et al.,* 2002). Problems like dry eye can possibly be caused by surfactants which may alter or reduce the surface tension of the tear film of the eye (Vejrup & Wolkoff, 2002). There are also reports on air particles which contaminated with surfactants can cause instability of mucus membrane in the respiratory system and thus lead to allergies and asthma (Zimmer *et al.,* 2002). Moshammer and Neuberger (2003) proposed that surface active particles could be used as exposure index for short term decrease of lung function. Although studies on surfactants' involvement in promoting an IgE response are scarce, Poulsen et al. (2002) suggested that IgE-mediated allergic diseases, such as asthma and rhinitis are increasing in industrialized societies and surfactants from the increased use of more effective and aggressive detergents is the reason for its occurrence. A rather large number of publications are available on the occurrence of biocides, plasticizers, flame retardants, heavy metals etc. in house dust, but data for surfactants are rare. Hence, the purpose of this particular study was to determine the concentration of surfactants in anionic and cationic form in indoor dust that may mainly be caused by synthetic surfactants, particularly in Malaysia. The possible sources of surfactants in indoor dust are also discussed in this work. In addition, correlation between surfactants and anions like chloride, nitrate and sulphate is also discussed.

MATERIALS & METHODS

Four sampling housing areas in Malaysia with different background were chosen for the determination of natural surfactants concentration in indoor dust namely Kuang, Taman Setapak Permai, Bandar Sri Putra and Nilai which represent rural, urban, construction, and industrial areas respectively. Kuang is located near a forest and with no heavy traffic reported there, it means there is no pollution from motor vehicles that can influence the concentration of surfactants. On the other hand, Taman Setapak Permai which has high density population with many human activities and the road is always busy with motor vehicles, especially during peak hours. Bandar Sri Putra is located near a highway heading to Nilai. It is a new housing area and so construction works are still going on. This particular activity ought to give effects on the concentration level of surfactants in indoor dust around the region. The industrial area of Nilai is a place where several factories such as processing palm fruit factory are located. The smoke released by the factories might influence the overall concentration level of surfactants there.

Dust samples were taken at the surface of exposed furniture around the hall (fan, cupboard etc).The reason for choosing dissimilar surroundings of the housing area was to study the correlation between the backgrounds with surfactants concentration in indoor dust. All samples were taken by slowly sweeping the substrates with a fine brush into a closed container before being analyzed in the laboratory.

For comparison, street dust sample outside the residence was collected and the sampling method was the same as there for indoor dust sampling. The site was chosen near the houses and the street dust was taken by slowly sweeping the substrates with a fine brush into a closed container. The dust samples were filtered with a 63 µm pore size filter. Then, 50 mg of the filtered sample was put in a volumetric flask and ultra-pure water was added until it reached 100 mL. The mixture was sonicated and filtered through a Whatman cellulose acetate filter (pore size 0.2 µm) under vacuum. Surfactants analysis could be carried out afterwards.There were some parameters that were chosen including the influence of cooking and smoking activities on the surfactants concentration. These activities included burning that released organic substances which could be modified to surface-active agent. Table 1 shows the comparison between activities stated between three sampling stations for each site.

The principle of the method in the determination of surfactants is based on the formation of ionic complex between anionic surfactants and cationic dye and vise versa before spectrophotometric measurement of the intensity of the extracted compound. Methylene blue was used extensively in the determination of surfactants in the aqueous phase (Longwell & Maniece, 1955; Yamamoto & Motomizu, 1987; Chitikela *et al.,* 1995; Matthjis, 1997; Sukhapan, 2002). The correlation study also included other pollutants that were anions eg. chloride (Cl^-),

Table 1. Comparison between cooking and smoking activities between sampling stations

Surroundings of the site	Station 1		Station 2		Station 3	
	Cooking	Smoking	Cooking	Smoking	Cooking	Smoking
Rural	Yes	Yes	Yes	No	No	Yes
Urban	Yes	No	No	No	Yes	Yes
Construction	Yes	No	Yes	No	Yes	No
Industrial	Yes	Yes	Yes	Yes	Yes	Yes

nitrate (NO_3^-) and sulphate (SO_4^{2-}). Anions chloride (Cl^-), nitrate (NO_3^-) and sulphate (SO_4^{2-}) were chosen as they are the indicators for atmospheric pollutants. The anionic composition of aerosols is predominated by acid precursors: sulphate, nitrate and chloride (Pandey *et al.*, 1998).

The concentrations of these anions were compared to the surfactants concentration. They were analyzed using ion chromatography, IC (Metrohm 09188) which is an analytical method for ionic species. IC is an extracting technology which uses ion extraction column to extract ions that pass through it followed by measurement at the end of the column by a detecting system.

RESULTS & DISCUSSION

Anionic surfactants concentration as MBAS and cationic surfactants concentration as DBAS in indoor dust for each site is shown in Table 2.

Table 2. Concentration of MBAS and DBAS in indoor dust

Site	Indoor Dust Concentration (µmol/g)	
	MBAS	DBAS
Rural	6.12 ± 1.68	1.48 ± 1.39
Urban	3.27 ± 0.51	1.60 ± 1.32
Construction	4.55 ± 1.36	1.64 ± 1.03
Industrial	5.03 ± 0.62	0.71 ± 0.21

Note: n value for each station in each site is 4 times (n=4)

Fig. 1. shows that the rural area indicates the highest MBAS concentration, whereas the urban area has the least concentration of MBAS that is 3.273 ± 0.514 µmol/g. There is a significant difference between the concentration of MBAS in the rural area compared to the urban area ($p<0.05$). The lower concentration of MBAS in the urban area is possibly caused by the life style of the citizens who spend most of the time in the workplace than at home. Hence, indoor activities such as cooking etc. are not as frequent as in the rural area. Besides, uncovered red soil path causing soil dust is easily taken by the wind into the houses.

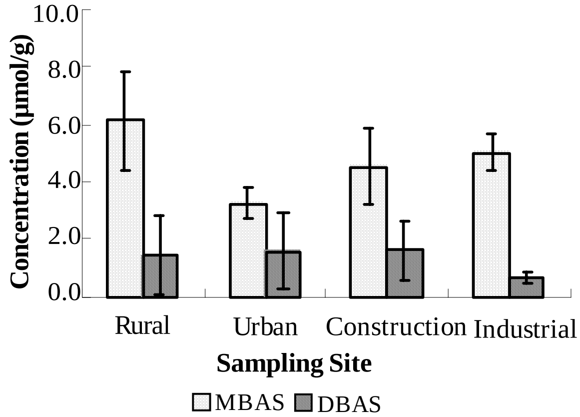

Fig. 1. Concentration of MBAS and DBAS in indoor dust for each site

As for the DBAS concentration (Fig.1). the construction area recorded the highest concentration while the industrial area recorded the least. Statistic analytical (ANOVA) indicates that there is a significant difference between both sites ($p<0.05$). In indoor dust, MBAS concentration is much higher than DBAS concentration in each site studied. This result is similar with a study done by Butte et al. (2004) which reported that cationics surfactants were present in some ten and anionics in some hundred milligram per kilogram in house dust. This was due to the various factors that may contribute to the high concentration mainly caused by human activities indoor and also from the surroundings. Activities that involved burning included cooking, smoking and using the mosquito repellent coil (Juliana *et al.,* 2001) were the main activities indoor. As the samples were taken from the furniture, the level of the MBAS concentration can easily be present by the use of cleaning detergent. So far, surface active material that was usually used was anionic where the percentage of usage was between 70-75%.Surfactants in detergent cause the cleaning solution to wet the surface (cloths and dishes) quicker so the dirt will be easily cleaned (Matheson, 1996). Anionic surfactants concentration as MBAS and cationic surfactants concentration as DBAS in street dust for each site is shown in Table 3.

Table 3. Concentration of MBAS and DBAS in street dust

Site	Street Dust Concentration (µmol/g)	
	MBAS	DBAS
Rural	1.01 ± 0.03	0.48 ± 0.11
Urban	1.11 ± 0.18	0.39 ± 0.18
Construction	0.83 ± 0.11	0.38 ± 0.30
Industrial	1.00 ± 0.29	0.45 ± 0.09
Note: n value for each station in each site is 4 times (n=4)		

The urban area indicates the highest concentration of MBAS with 1.113 ± 0.181 µmol/g whereas the lowest is at the construction area (Fig. 2). Anionic surfactants in street dust came from the atmosphere which the surfactants adsorbed onto particles or aerosol and subsequently precipitated onto surface of soil or street. The high level of MBAS was also contributed by unfinished burning by vehicles as the traffic in this area was very busy. Previous studies by Thomas et al. (1999) and Venkataraman et al. (1999) reported that diesel-exhaust particles or soot particles were the main causes of urban pollution. It is probable that the adsorption of anionic surfactant molecules essentially occurs through dispersive interactions between the non-polar organic tail group of the adsorbing molecule and the hydrophobic part of the graphitized soot surface (Ghzaoui *et al.,* 2004).

In contrast with the early hypothesis, the rural area shows the second highest level of MBAS concentration with 1.008 ± 0.033 µmol/g. It may have been caused by open burning that frequently resulted from anthropogenic activities. The industrial area also shows a significant high concentration level of MBAS as the site is in the vicinity of a palm processing factory and others. The smoke from the factories which is saturated with particulate matter adds to the generating of anionic surfactants in the atmosphere.

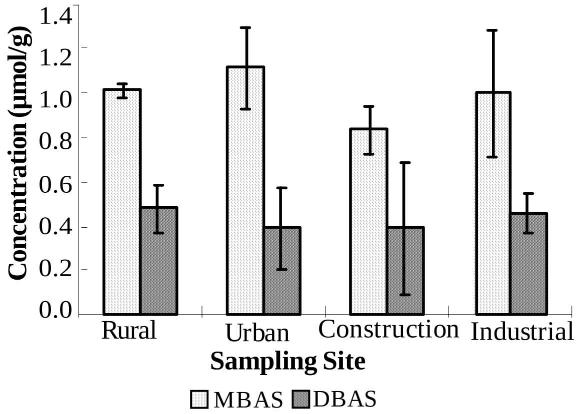

Fig. 2. Concentration of MBAS and DBAS in street dust for each site

The concentration level of DBAS was highest at the rural area (0.475 ± 0.107 µmol/g) followed by the industrial, urban and construction area (Fig.2). However, there was no significant difference for all study sites ($p>0.05$). As in indoor dust, the concentration level of MBAS was much higher than DBAS in street dust. Most of the surfactants in atmospheric aerosols were negatively charged (Latif & Brimblecombe 2004). Latif et al. (2005) also obtained similar result as the concentration of anionic surfactant in aerosols recorded was very high compared to cationic surfactants and suggested that human activities, for instance fuel burning from motor vehicles, industrial bustle and open burning may have largely contributed to the level of MBAS concentration in the South-East Asia compared to natural sources such as sea surface micro layer. Sources of cationic surfactants, on the other hand are very limited, that is from nitrogen-based organic compound.

Fig. 1. and Fig. 2. indicate that level of MBAS and DBAS are higher in indoor dust compared to street dust. This is mainly caused by various sources of anionic surfactants in indoor environment compared to the street dust. Synthetic surfactants that play a major role in most consumer products (Myers, 1988) can be one of the sources of both anionic and cationic surfactants in indoor dust but not in the street dust.

Moreover, according to Rasmussen et al. (2001), dust that is generated from sources within the house itself can contribute significantly to exposures to certain elements. Table 4 shows the concentration level of anions (chloride, nitrate and sulphate) in indoor dust for each site. In this study, the sequence of concentration level was as follows, $Cl^- > NO_3^- > SO_4^{2-}$ which was slightly differ from previous study by Latif et al. (2006), $Cl^- > SO_4^{2-} > NO_3^-$.

Table 4. Concentration of anions chloride, nitrate and sulphate in indoor dust

Site	Indoor dust Concentration (µmol/g)		
	Cl^-	NO_3^-	SO_4^{2-}
Rural	142.21 ± 27.12	154.44 ± 100.71	12.35 ±1.23
Urban	137.15 ± 29.72	20.23 ±18.23	11.16 ± 5.37
Construction	169.95 ± 5.67	39.63 ± 0.87	10.60 ± 0.64
Industrial	167.02 ± 21.50	48.12 ± 14.53	10.67 ± 2.62

Chloride was found higher at the construction area with 169.948 ± 5.672 µmol/g and lowest at the urban area (Fig. 3). Tap water and detergent containing chloride which was used for cleaning purposes were considered to be the main source of chloride in indoor dust (Latif *et al.*, 2006). Elements produced during combustion usually appear in the form of oxides such as magnesium, aluminum, titanium, silicon dioxide, calcium and iron trioxides, phosphorus pentoxide, ammonium sulfate, and sodium chloride (Miranda & Tomaz, 2008). Hence, activities such as smoking and cooking contribute to chloride in indoor dust.According to Fig. 3. nitrate ion was found highest in the rural area followed by the industrial, construction and urban area. Usually nitrate is formed from the oxidation process of nitrogen dioxide. Natural gas burning from cooking activities will eventually release nitrate together with other factors that contribute to the concentration level of nitrate in indoor dust such as air flow and other nitrate source. The highest concentration level of sulphate is in the rural area. There are many sources of sulphate in indoor dust including aerosol spray, cooking and smoking activities (Morawska *et al.*, 1995) and also burning activity.

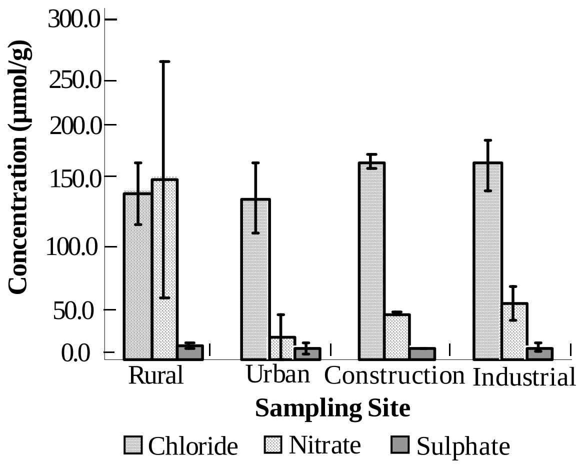

Fig. 3. Concentration level of chloride, nitrate and sulphate ions in indoor dust

Overall, the concentration level of chloride was found higher than nitrate but no figures for sulphate anion were recorded in the street dust for each site (Table 5 and Fig. 4). According to Bastviken et al. (2007), it appears as if soil sometimes acts as a sink of inorganic chlorine (i.e. chloride, Cl_{in}) and sometimes as a source. Hence, chloride ion can easily release to the atmosphere.As for nitrate, it is the final product from bacteria activity in soil. Sulphate cannot be detected in the street dust which probably has been absorbed deep into the soil as its sesqui-oxides act as sorbent to absorb sulphate compound from acid rain (Harrison *et al.*, 1989).

Table 5. Concentration of anions chloride, nitrate and sulphate in street dust

Site	Street dust Concentration (µmol/g)		
	Cl^-	NO_3^-	SO_4^{2-}
Rural	59.75	16.58	-
Urban	73.40	59.12	-
Construction	69.45	69.02	-
Industrial	17.66	32.29	-

Indoor environment can be polluted by sources from the surrounding itself and from outdoor sources (Niu & Burnett, 2001; Bhargava *et al.*, 2004; He *et al.*, 2004; Brims & Chauhan, 2005). Fig. 5 and Fig. 6 show the correlation of concentration level of MBAS and DBAS between indoor dust and street dust respectively. It clearly indicates that MBAS and DBAS level in indoor dust is not largely derived from the street dust.

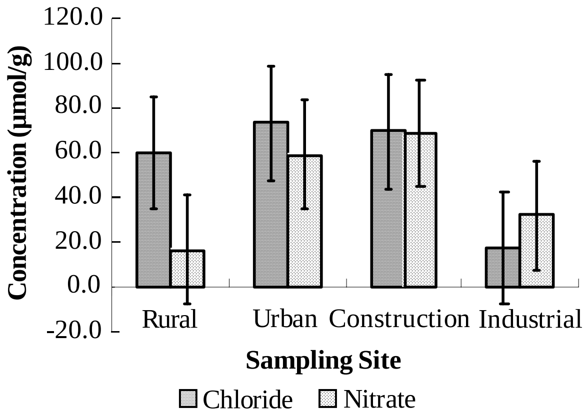

Fig. 4. Concentration levels of chloride and nitrate ions in street dust

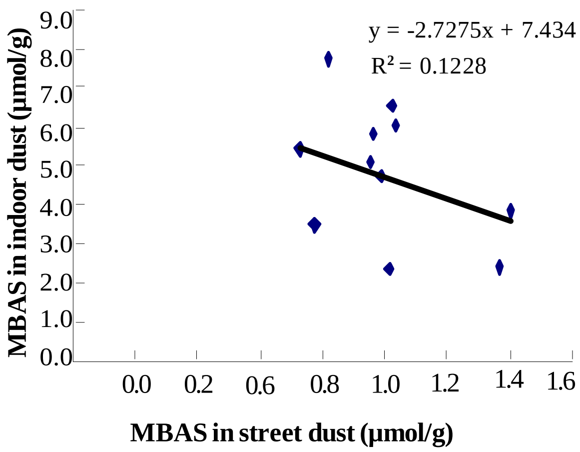

Fig. 5. Correlation of MBAS level between indoor dust and street dust

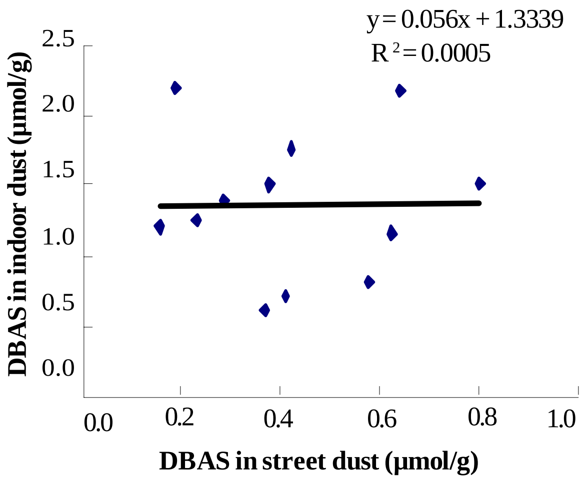

Fig. 6. Correlation of DBAS level between indoor dust and street dust

The correlation study between anionic surfactant as MBAS and nitrate indicated the highest value of R^2 with 0.2469 (p>0.052)(Fig. 7). As nitrate is the major product from burning process, this result shows that anionic surfactants in indoor dust came from anthropogenic activities, for instance cooking which involved the burning of natural gases.

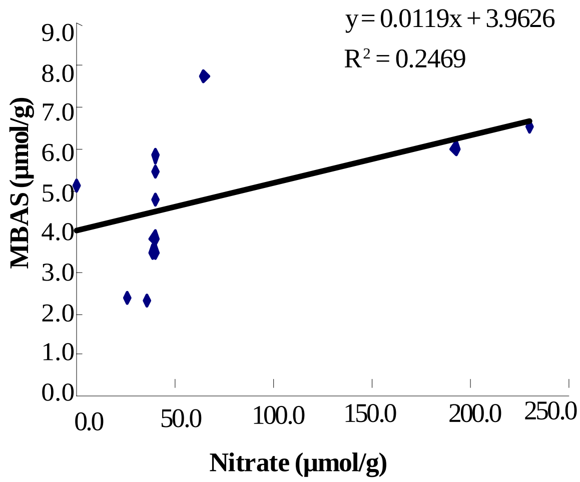

Fig. 7. Correlation between MBAS and nitrate ion in indoor dust

CONCLUSION

The finding indicates that the concentration level of anionic surfactants as MBAS and cationic surfactants as DBAS is higher in indoor dust than in street dust. It also shows that anionic surfactant is more dominant in the atmosphere. Around 77.8 % of surfactants in indoor dust are anionic while 22.2% are cationic. For the street dust, 70% of surfactants are anionic whereas the other 30 percent are cationic. In this study, the rural area happened to have the highest level of MBAS and this was due to the lifestyle of the residents. Even though the outdoor surrounding can influence the concentration level of surfactants indoor, but their main contributor were anthropogenic activities inside the house itself. Surfactants that come from human activities can be reduced for instance by burying the garbage instead of burning them and minimizing the use of mosquito coils, aerosol spray and detergent and also smoking activity. This is very crucial especially to human health as many studies have suggested that surfactants can promote various kinds of diseases. Further studies on the composition of detergents (surfactants) can be done to understand its correspondence to human health.

ACKNOWLEDGEMENT

This research is supported by Universiti Kebangsaan Malaysia Grant (STGG-004-2007) and Research University Grant (UKM-GUP-ASPL-07-05-138)

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