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Extraction Rate of Low Concentration Organic Vapor Adsorbed in Activated Carbon Tube for Work Environment Measurement in Japan

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Measurement technique of harmful substances, particularly various organic vapors in air has a significant role in administration and improvement of work environment. We can measure high levels of organic vapors directly by several types of gas sensor or indicator today. However, low concentration of organic vapors (~dozens ppm) is beyond detection or difficult for precise measurement on its own in many cases. Therefore, in work environment measurement established by the industrial safety and health act of Japanese government, activated carbon tube (sampling tube) is used for sampling of measuring object vapor by concentrating method with aspiration pump unit. That is, after the concentrated sampling for a given length of time, measuring object constituent is extracted by organic solvent (for instances; carbon disulfide, acetonitrile, methanol and so on) from activated carbon. Then, the liquid samples are measured by gas chromatograph. The above method is called solid substance collecting method, and measurements are administered in reference to control concentration at 298 K established by the workplace evaluation standard of Japanese government.

However, the method has also defects. Particularly, depending on types of organic vapors and circumstances, extraction rate of the object constituent from activated carbon becomes low, and the phenomenon makes accuracy of measurements extremely worse. The effect is clear particularly in the case of low concentration vapors and small collection amount by activated carbon, and two main factors are expected for reason of the phenomenon. For one thing, collection capability of activated carbon tube differs for each type of organic vapor. Further, conventional activated carbon has narrow size distribution of pore development (conventional activated carbon is called typical "microporous carbon material" in material science), and it makes realization of enough high adsorption and desorption rates of measuring object constituent difficult.

Some previous papers [1,2] report current example of measurements regarding extraction rates by existing activated carbon tube product, and they points several types of organic vapors (for instances; aromatic compounds, alcohols, ketones, cellosolves and acetate esters) which show low rates as compared with other chemical compounds. Particularly, the papers reported that 6 type organic vapors (Toluene, 1−Butanol, Acetone, Ethylene glycol monoethyl ether (EGEE), Butyl acetate and Cyclohexanone) show extraction rates below 96% even in higher concentration region above 0.5E (E is control concentration (Table 1)).

However, the previous papers [1,2] treated only the same one type of activated carbon tube product in Japan. Furthermore, extraction rates in lower concentration region below 0.5E are still not clear for almost existing products. The situation has problem in consideration of low and ultralow concentration organic vapors control in work environment. The information of extraction rates in the lower region is also necessary and helpful for using of the sampling tube products. Regarding this problem, we will measure extraction rates of each sampling tube product in the low concentration region and figure out their details in the days ahead. In particular, using 7 existing activated carbon tube products, we will measure extraction rate of the compound mainly on aromatic compounds, alcohols, ketones, cellosolves and acetate esters with the low concentration <0.5E in detail.

Some measurement example by our research is described as follows. Measurements of extraction rate by each activated carbon sample were carried out by reference to the phase equilibrium method described in the working environment measurement guidebook (edited by the Japan association for working environment measurement) in Japan [3]. The measuring object constituents in the experiments are Toluene, 1−Butanol, Butyl acetate and Cyclohexanone.

Test liquid solutions corresponding to 0.025E, 0,05E, 0.5E and 1.0E (collection air content 5L at 298K) are prepared by the conditions

Organic vapor	Control concentration / ppm
Toluene (Aromatic compound)	20
1−Butanol (Alcohol)	25
Acetone (Ketone)	500
Cyclohexanone (Ketone)	20
EGEE (Cellosolve)	5
Butyl acetate (Acetate ester)	150

Table 1: Examples of control concentration of organic vapors at 298K established by the workplace evaluation standard of Japanese government (2013).

Preparation Condition	Detail
Extraction organic solvent	Carbon disulfide (CS_2)
Measuring object constituents	Toluene, 1−Butanol, Butyl acetate, Cyclohexanone
Additive amount at 1.0E / ml (CS_2)	Substantial amount of air content 5L at 298K
Preparation concentration	0.025E, 0,05E, 0.5E, 1.0E

Table 2: Preparation conditions of test liquid solutions for measurements of extraction rates of an activated carbon tube product. E is the control concentration of organic vapors indicated in Table 1.

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Organic vapor / Concentration	0.025E	0.05E	0.5E	1.0E
Toluene	0.87 (± 0.01)	0.91 (± 0.06)	0.98 (± 0.08)	0.94 (± 0.09)
1−Butanol	0.80 (± 0.01)	0.82(± 0.07)	0.95 (± 0.07)	0.98 (± 0.04)
Cyclohexanone	0.88 (± 0.03)	0.88 (± 0.06)	0.96 (± 0.02)	0.97 (± 0.04)
Butyl acetate	0.89 (± 0.04)	0.90 (± 0.06)	0.98 (± 0.07)	1.00 (± 0.04)

Table 3: Extraction rates measurement data of an activated carbon tube product with change of concentration of object organic vapors (N≒3). E is the control concentration of organic vapors indicated in Table 1.

indicated in Table 2. We used products of Wako Pure Chemical Industries Ltd. for each organic solvent. In each measurement, a certain amount (~approximately 100 mg) of activated carbon sample, which is brought out from a sampling tube product was used. Test liquid solution approximately 1 ml is added to each activated carbon sample in a vial container. After an hour, liquid sample was measured by gas chromatograph using a microsyringe. We used a gas chromatograph SHIMADZU GC−14B, which is equipped with FID (hydrogen flame ionization detector) detector, and C−R8A Chromatopac data processor for measurements of extraction rate. Helium gas (>99.995%) was used as carrier gas for each measurement, and extraction rate of each sample was calculated from peak area of data by the gas chromatograph system (Table 3). The results in Table 3 show the above mentioned inclining of extraction rates due to change of concentration of object organic vapors certainly.

Extraction rates of object constituents from activated carbon are expected to be affected by types of extraction solvent and measurement technique in using gas chromatograph equipment. In addition, porous carbon material which has wide pore size distribution and development [4], which is called mesoporous materials in material science, seems to have good effect on improvement the above phenomenon of extraction rates of existing activated carbon. We will also investigate the above points in detail in the future.

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