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Resistance of IIR Barrier Materials against Selected Chlorinated Hydrocarbons

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Abstract:

Information about quality assurance means insulating protection is very important. Their availability may be limited, and therefore in some cases will need to rely on the value of breakthrough times for basic hydrocarbons which are not substituted. The article describes how to test breakthrough times of the protective foil based on a polyamide carrier fabric coating butyl-rubber polymer mixture measured by the linear substituted saturated chlorinated aliphatic hydrocarbons.

Keywords:

Chlorinated hydrocarbon, QCM detector, permeation rate, butyl-rubber (IIR), breakthrough time (BTT), chemical permeation resistance, permeation cell.

1. Introduction

The knowledge about resistance of means of body surface protection against under interest toxic compounds is important not only for protective means' users but also for workers who either manage or plan the activities in a contaminated area. Protective properties of protective means against a particular kind of contaminants are not always known. In a case of necessity to work in the contaminated area, however, two approaches exist. Neither enter the contaminated area after contamination with a chemical substance for which values of breakthrough times (BTT) are unknown nor to expertly assess the constructive material's resistance for an under interest substance. The BTT's value affects many factors such as temperature, concentration of harmful substance, quantity of contaminant (small drops or massive contamination), way of contamination (liquid or vapours), the type of barrier layer and its thickness. BTTs'

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values also affect humidity and time for which the protective means were used. In case of known BTT for the particular chemical substance and its relationship to the type of protective means, it is not necessary to mutually combine constructive materials. If it is not kept the lack of information can be an obstacle for skilled estimation of another kind of barrier material's resistance for under interest contaminant. In such a case it is possible to be fully concentrated only on outer factors such as temperature, the contaminant's type and contaminant's concentration. These factors have to be always accompanied by the description of toxic agent concentration and information concerning samples' properties.

2. Problems of both Finding and Assessment of BTTs with the Help of QCM Detection

Finding of materials' BTTs is performed for an under interest chemical compound's liquid phase as a rule. Although, it is done from a reason of both creation of maximal concentration gradient and the indemnity of constant conditions for permeation of chemical compounds through barrier materials within practical employment in real conditions either it is not going to be reached or quite exceptionally for a short period of time. That is why it is possible to reduce the estimation of chemical resistance only for mutual similarity of a chemical compound structure and a character and type of substituent for them values of BTTs are known. For the estimation of resistance it is important to consider the temperature within the activity is going to be running.

Measurement of chemical resistance of isolative protective foil used for construction of means of body surface protection is conducted in accordance to standard ČSN EN ISO 6529 [1] (in case of European Union EN ISO 6529). The permeation resistance of protective means is indicated with the selection into classes according to the standard of ČSN EN 340 (83 2701) [2]. For estimation of chemical resistance (BTTs) is, however, necessary to know not resistance of particular means in conformity with the standard (it means in accordance of classes) but in keeping with time of resistance, which is actually BTT. This information has more commercial importance which can be measured with other methods (conductivity, colorimetric principle etc.). For BTTs introduced in this paper an apparatus used a reversible QCM sensor with polymeric detection layer has been employed [3-5]. A principled set of both the permeation cell for measurement in static conditions with inbuilt QCM sensor arrangement and measurement device is stated on Fig. 1.

The QCM sensor detector with the polymeric detection layer works as a very sensitive microbalance. The caught chemical compound in its polymeric layer causes a change of the QCM detector working frequency. Due to this QCM detector behaviour the time of loss of protective properties can be found and afterwards analysed. In practice it is done from the increase of change of the QCM detector working frequency in time. The particular time of protective properties loss has been, in accordance with Bronwich [6], read as so called Lag-Time, t_l, [min]. Lag time basically expresses the value of the steady state of permeation rate through researched constructive material. The slope of a part of the curve expressing steady state of permeation rate informs us about the rate of factual loss of protective properties of researched isolative material, thus about concentration of harmful substance increasing on underside of protective means.

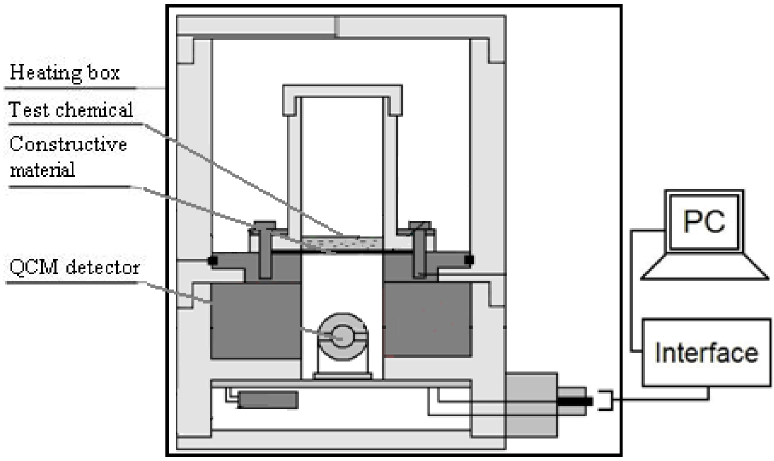

Fig. 1 Scheme of permeation cell and device with QCM detector for nonporous impermeable protective foils' chemical permeation resistance measurement in static conditions

3. Measurement Results and their Discussion

Breakthrough times for selected chlorinated hydrocarbons have been measured with the help of permeation cell equipped by the QCM detector with the polymeric layer. Butyl-rubber isolative protective foil with the carrier layer made from a polyamide fabric with double-faced deposit with an overall weight of 400 g/cm^2 has been employed for measurement of BTTs. Measurements have been performed in the temperature of 30 °C. The researched fabric has been up interlaced with 2 cm^3 of test chemical in a permeation cell's dosing area. Measurements' results of fabric's resistance for selected saturated chlorinated hydrocarbons are summarised in Table 1.

Tab. 1 BTTs values for selected chlorinated hydrocarbons

Chemical compound	**Minimal value of BT [min]**	**Minimal value of researched material thickness [mm]**
Dichloromethane	6.9	0.349
1,2-dichloroethane	7.3	0.335
Trichloromethane	6.2	0.346
1,1,2-trichloroethane	18.3	0.332
1,3-dichloropropane	18.1	0.335
Tetrachloromethane	21.7	0.351
1,1,2,2-tetrachloroethane	46.8	0.348
1,6-dichlorohexane	78.7	0.333

If BTTs of researched nonporous protective foil with barrier layer made from IIR is compared in accordance with a chemical structure of test chemical it can be seen that test chemical's chemical structure affects permeation. The dependence of BTT on the test chemical's chemical structure is evident from Fig. 2.

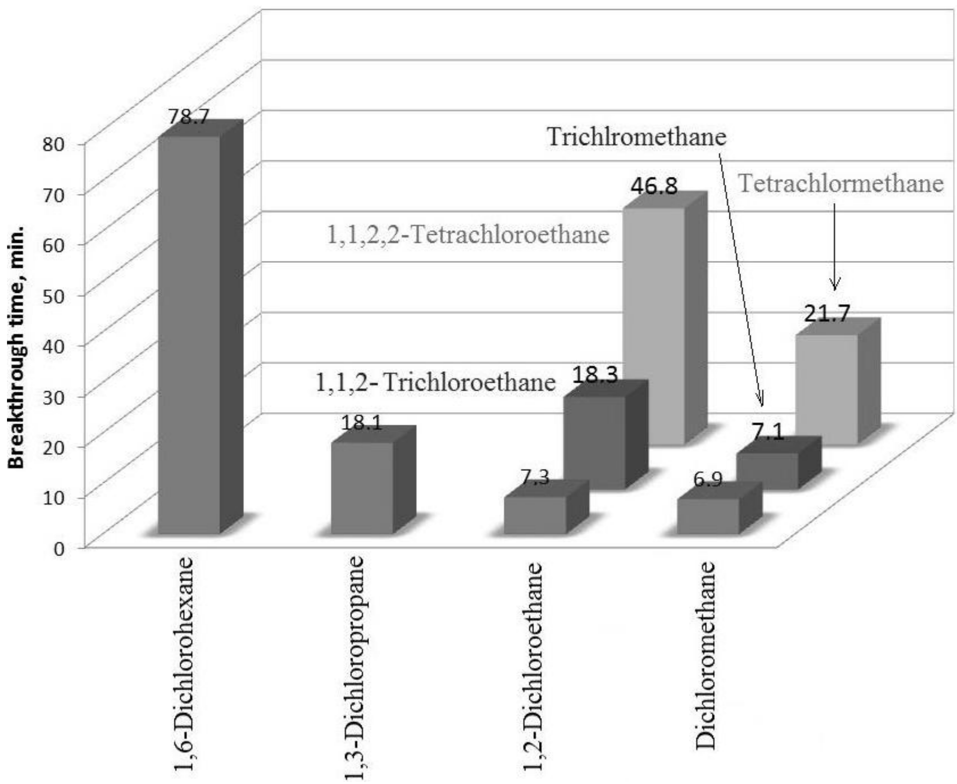

Fig. 2 Dependence of BTT of isolative protective fabric with barrier layer made from IIR on the chemical structure of test chemicals.

From dependence of the change of QCM detector working frequency on time for single test chemical it is clear that researched nonporous impermeable protective foil for all tested chlorinated hydrocarbons shows quick loss of protective properties (Fig. 3). This loss (i.e. increase of permeation rate) can be characterized with the help of an angle which includes a linear part of dependence with time axis. It is generally valid that the higher angle (max. 90°) points to the protective foil which is more "open" for permeation of test chemical and thus its concentration can quicker increase under mean part of protective means.

Based on performed measurements a relationship between resistance values and test chemicals' properties has been searched. Based on analyses of available data such as suitable value which would characterize relationship between nonporous impermeable protective foil with resistance of barrier material made from IIR and saturated linear chlorinated hydrocarbons, the permeation rate of molar value has been used (Table 2).

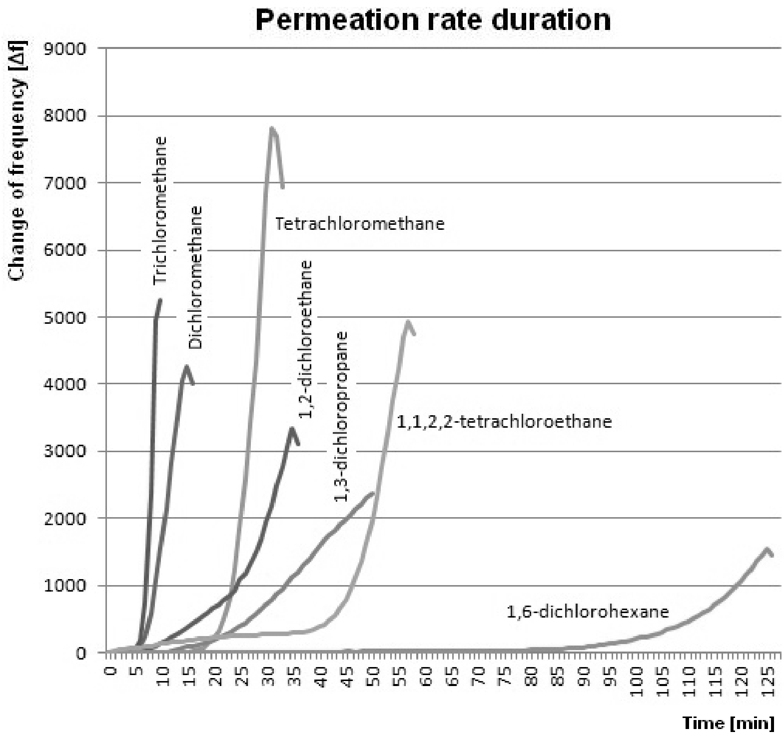

Fig. 3 Dependence of working frequency of QCM detector on time for selected chlorinated hydrocarbons

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Tab. 2 Relative molar mass, molar volume of selected chlorinated hydrocarbons, BT and thickness of measured isolative protective foil

Chemical substance	**Molar mass [g/mol]**	**Molar volume [cm^3/mol]**	**Minimal value of BTT [min]**	**Mean value of BTT [min]**
Dichloromethane	83.93	63.857	6.9	7.2
1,2-dichloroethane	98.96	79.168	7.3	9.9
Trichloromethane	119.38	80.662	6.2	6.5
1,1,2-trichloroethane	133.41	92.638	18.3	21.9
1,3-dichloropropane	112.99	94.949	18.1	23.6
Tetrachloromethane	153.82	96.742	21.7	22.5
1,1,2,2-tetrachloroethane	167.85	105.566	46.8	50.5
1,6-dichlorohexane	155.07	144.925	78.7	87.4

From Table 2 it is evident that values of molar weight well correspond with values of BTTs irrespective the fact that BTTs values are affected by thicknesses of isolative protective foil.

It is clear that this approach will be valid only for the group of chemical compounds which chemical structure will not be dramatically different, for example within homologues, alkyl benzenes with different degree of alkylation etc.

4. Conclusion

Estimation of the chemical resistance of protective isolation foil based on the similarity of chemical substances' structure can be, mainly concerning highly toxic substances, one of the possible approaches to predict the risk for people working in a contaminated environment. In this case the health hazard caused by improper and mainly long-term use of isolative protection equipment can be significantly reduced.

References

[1] EN ISO 6529:2006 *Protective clothing – Protection against chemicals – Determination of resistance of protective clothing materials to permeation by liquids and gases.*

[2] EN 340:2004 *Protective clothing – General requirements.*

[3] Author's certificate No. 2484. PV 5531-85 [1985-07-29].

[4] OBŠEL, V. Quartz Crystal Microbalance Technology for Testing of Protective Means. *CBRNe WORLD*, Winter 2008, p. 77-78. ISSN 2040-2724.

[5] FLORUS, S., OTŘÍSAL, P. and OBŠEL, V. Possibilities of usage a piezoelectric detector to measure the breakthrough time of protective materials. In *Conference Proceedings of the 7th Symposium on CBRNE threads "Meeting the future challenges".* Jyväskylä: Defence Forces Technical Research Centre, 2009, p. 239-243.

[6] BROMWICH, D.W. *The Design of Permeation Cells for Testing Chemical Protective Clothing.* Brisbane: Griffith University, 1999, 381 p.

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