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USING THE TOPOLOGICAL INDEX ZEP IN QSPR STUDIES OF ALCOHOLS

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ABSTRACT The paper is devoted to the modelling of a class of molecular compounds containing heteroatoms (alcohols) by means of the concept of weighted electronic distance and the corresponding connectivity matrix CEP. A topological index derived from this matrix, the ZEP topological index, is then correlated with the boiling point (BP) and the water solubility (log(1/S)) of alcohols, using simple and multiple linear regression analysis. In order to improve the simple models we also calculated a novel parameter, H_d, derived from the usual topological distances between the vertices of the graph. The obtained results indicate the combination of ZEP and H_d indices as a promise in the QSPR analysis of complex compounds.

Keywords: weighted electronic distance; CEP connectivity matrix; ZEP topological index; parameter H_d, linear regression analysis.

INTRODUCTION

A chemical compound can be represented by using the concept of molecular graph *G*. A molecular graph can itself be represented by several topological matrices [1-4]. The most used matrices are the adjacency matrix, *A*=*A*(*G*), and the distance matrix, *D*=*D*(*G*). The mathematical modelling of chemical structures by using descriptors derived from the molecular graphs, by means of topological matrices, has grown rapidly in the last decade [5-7]. Among these descriptors, the topological indices have been widely used in QSPR (Quantitative Structure-Property Relationship) and QSAR (Quantitative Structure–Activity Relationship) analysis. Both adjacency and distance matrices, in their original form [2-4], are appropriate for modelling chemical compounds with no multiple bonds or heteroatoms. When structurally different molecules, such as isobutane, isobutene, 2-propanol, 2-cloropropane, 2-aminopropane, are under study, difficulties appear in amending the classical topological matrices to account for there structural differences. The question how to represent the multiple bonds and/or heteroatoms, gained more than one answer.

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A first approach to represent heteroatoms and multiple bonds has been proposed by Kier and Hall [8], and also by Barysz and collaborators [9]. Basak and collaborators [10] have treated the presence of heteroatoms by applying the information theory. The method proposed by Balaban [11], considers the electronegativities, the atomic number and the number of the group in Mendeleev's short form of the periodic chart. The same problem has been also tackled successfully by Randić [12], and Estrada [13].

In the present paper we shall treat the presence of heteroatoms, especially those in the alcohols class, by means of the weighted electronic distance (w.e.d.), a new local invariant considered by the author in [14]. By replacing the usual topological distances from the adjacency matrix, by the values of the weighted electronic distances, we obtain a new connectivity matrix, CEP, used for the construction of some topological indices [14-16]. Such a topological index is the ZEP index, which is correlated in this paper to the boiling point (BP) and the water solubility (log(1/S) for aliphatic alcohols.

The weighted electronic connectivity matrix and topologic ZEP index

For a molecule having N atoms, whose graphs is G = (V(G), E(G)), the weighted electronic connectivity matrix, CEP(G), is a square N x N matrix given by:

$$CEP\ (G)=\left\{[CEP\}_{i,j};\quad i,j\in V(G)\right\} \tag{1}$$

where its entries $[CEP]_{i,j}$ are defined as follows:

$$CEP_{ij}=d.e.p.(i,j),\ if\ i\neq j \text{ and } (i,j)\in E(G) \text{ and } CEP_{ij}=0 \text{ otherwise} \tag{2}$$

and:

- d.e.p. (i, j) denotes the weighted electronic distance between the atoms (vertices) i and j;
- V(G) is the set of all vertices (atoms) of the moleular graph G;
- E(G) is the set of all edges (bonds) of the graph G;

The weighted electronic distance, w.e.d. was recently defined in [14] by the formula:

$$w.e.d.(i,j)=\frac{1}{b_r}\cdot\frac{Z_i^{'}+Z_j^{'}}{v_i\cdot v_j} \tag{3}$$

where

- b_r is the bond weight (or bond order) with values: 1 for single bond, 2 for double bond, 3 for triple bond like in Barysz et al. [9]

- ν_i denotes the degree of vertex i (that is, the number of bonds of the atom i to other atoms),

- $Z_i^{`}$ denotes the formal degree of vertex i, it is defined by:

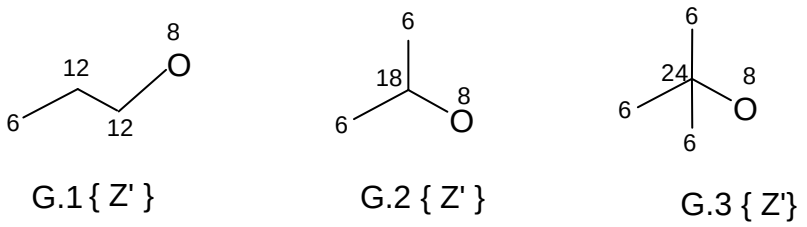
$$Z_i^{`} = Z_i \cdot \nu_i \tag{4}$$

- Z_i being the order of the atom i (that is, the number of all electrons in the atom i).

Similar formulas which use the atomic number and the multiplicity order of bonds have been considered in an other context by Barysz and collaborators [9], where it is detected only the presence of multiple bonds and heteroatoms, but their model is not able to reproduce the information related to the neighborhood of bonds, as in the case of weighted electronic connectivity.

The formal degree $Z_i^{`}$ of the vertex i is in fact a local invariant on vertex (LOVI), which replaces the classical degree of the vertex, while the weighted electronic distance, w.e.d. (i,j) represents a local invariant on edge (LOEI).

Having in view that for oxigen we have $Z = 8$, it results that its formal degrees will be $Z'_O = 8$ for alcohols. The carbon atom in the structure of an alcohol may have the formal degree Z'_j equal to 6, 12, 18 or 24, respectively. These aspects are illustrated in Figure 1, on the molecular graphs of 1-propanol (G.1), 2-propanol (G.2) and 2-methyl-2-propanol (G.3).



G.1 { Z' } G.2 { Z' } G.3 { Z'}

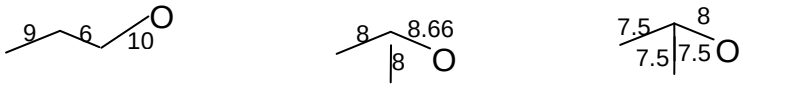
Figure 1. The graphs G.1, G.2 , G.3 and formal degrees (Z')

By replacing (4) in (3) and taking into account that $b_r = 1$, because the oxigen atom establishes only simple bonds in the class of alcohols, we obtain

$$w.e.d.(i, j) = \frac{Z_i}{\nu_j} + \frac{Z_j}{\nu_i} \cdot \tag{5}$$

The weighted electronic distances computed by means of equation (5) for the covalent bonds carbon–carbon and oxigen–carbon represent local edge invariants (LOEI).

On the edges of each graph in Figure 2 are written the w.e.d., computed by (5).

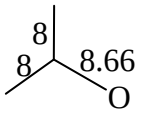


G.1{ w.e.d. } G.2 { w.e.d. } G.3 { w.e.d. }

Figure 2. The graphs G.1, G.2, G.3 and w.e.d.

Figure 3 shows the CEP matrix for 2-propanol whose graph, G.2, is depicted in the same figure, with the values of w.e.d. computed by formula (5).

SEP_i



G.2

$$CEP(G.2) = \begin{bmatrix} 0 & 8 & 0 & 0 \\ 8 & 0 & 8 & 8.66 \\ 0 & 8 & 0 & 0 \\ 0 & 8.66 & 0 & 0 \end{bmatrix} \begin{matrix} 8 \\ 24.66 \\ 8 \\ 8.66 \end{matrix}$$

Figure 3. The CEP matrix for 2-propanol

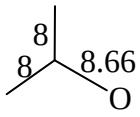
The sum of all entries on the i-th row in CEP(G.2) is denoted by SEP_i (and is written at the matrix right hand side):

$$SEP_i = \sum_{j=1}^{N} [CEP]_{ij}; \; i = 1, N \tag{6}$$

The electronic connectivity matrix can function as a basis for the construction of several new topological indices. The simplest index is given by the sum of root square of SEP_i:

$$ZEP = \sum_{i=1}^{N} (SEP_i)^{1/2} \tag{7}$$

The calculation technique of ZEP index is illustrated in Figure 4 for the hydrogen-suppressed graph G.2 of 2-propanol



$$ZEP(G.2) = 2 \cdot 8^{\frac{1}{2}} + 24.66^{\frac{1}{2}} + 8.66^{\frac{1}{2}} = 13.565$$

G.2

Figure 4. The calculation technique of ZEP index for the hydrogen-suppressed graph of 2-propanol

A novel parameter H_d

We propose now a novel parameter, denoted by H_d, which is calculated as the arithmetic mean of the distances from the heteroatom to the other atoms, using the usual topological distance between two vertices.

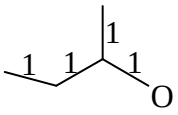
The parameter H_d is hence defined by the formula:

$$H_d = \frac{1}{n}\sum_{i=1}^{n} d_i \qquad (8)$$

where:

- n represents the number of carbon atoms in the molecular graph;
- d_i represents the distance between the heteroatom and the atom *i.*

The calculation technique of parameter H_d is illustrated in Figure 5 for the hydrogen-suppressed graph G.4 of 2-butanol



$$H_d = \frac{1}{4}(3+2+2+1) = 2$$

G. 4

Figure 5. The calculation technique of parameter H_d for the hydrogen-suppressed graph of 2-propanol (G.4)

ZEP and H_d could be used together in order to improve the QSPR models for several representative physical properties on several data sets of alcohols by using two-variable linear regression analysis.

RESULTS AND DISCUSSIONS

Correlations to normal boiling points (BP) of 132 alcohols

As a starting point, we consider a data set of 132 alcohols to develop the structure-boiling point model. The observed BP values for the normal boiling points at normal pressure are listed in Table 1 and were taken from [17].

Values of ZEP and H_d index were calculated for the same set of 132 alcohols and are presented in Table 1, too. A boiling point model is then generated using the ZEP index and H_d parameter.

The simple linear regression equation and its statistical parameters for a monovariable correlation with ZEP are shown below:

$$BP = 11.619 + 5.11\ ZEP;\ \ r = 0.960;\ s = 11.126;\ F = 1517;\ N = 132; \quad (9)$$

were: r-represents the correlation coefficient, s- the standard deviation and F is the Fischer ratio.

For the same 132 alcohols the simple linear regression with the ZEP index leads to a poorer correlation (r = 0.960 and s= 11.126 ^{0}C), comparable with the simple model obtained by Lu et al.[17] (r = 0.9665 and s= 9.797^{0}C). Obviously, a single ZEP index cannot give a simple and accurate correlation. It is important to stress that the statistical parameters of the QSPR equations could be improved by using multidimensional correlations involving also other topological descriptors. In this work we propose a combined use of the ZEP index and parameter H_d. The regression equation and its statistical parameters found to describe boiling points of the 132 alcohols considered are depicted below:

$$BP = 17.843 + 3.593\ ZEP + 12.391H_d;$$
$$r = 0.985;\ s = 6.794;\ F = 2143;\ N = 132 \quad (10)$$

Statistics indicate that equation (10) is a good model for calculating BP. Values of BP predicted by this equation are also shown in Table 1.

The statistical parameters of the model given by Eq. (10) can be compared to several results that have been reported elsewhere. The model found by Yang et al. [18] using the extended adjacency matrix EA∑ and EAmax indices gave r = 0.9837 and s = 6.35 for only 37 alcohols, while our model is applied to 132 alcohols, but the molecular connectivity ^1X and $^1X^v$ indices provided a slightly superior model to those using EA∑ and EAmax indices. Analogously, a multiple linear model constructed by Yao et al. [19] using X_{m1}, X_{m2}, and X_{m3} indices gave r = 0.987 and s = 7.4988 for the same series of 37 alcohols, while our model gave r = 0.985 and s = 6.794 for the richer series of 132 alcohols. Galvez et al. [20] reported that the three-parameter model using N (the number of the vertices) and two charge indices G_1 and J_2 gave r = 0.979 and s = 3.63 for 29 alcohols. Recently, Ren [21] developed a model by using AI and Xu indices and gave r = 0.9957 and s = 3.576 but only for the same restricted data.

Table 1. The index ZEP, parameter H_d and the experimental and calculated boiling points for 132 alcohols using Equation (10)

No.	Compound	ZEP	H_d.	BP (^{0}C)	
				Exp.	Calc.
1	1-propanol	14.035	2	97.1	93.1
2	2-propanol	13.565	1.667	82.4	87.2
3	1-butanol	17.499	2.5	117.6	111.7
4	2-methyl-1-propanol	17.274	2.25	107.9	107.8
5	2-butanol	17.166	2	99.5	104.3
6	2-methyl-2-propanol	16.566	1.75	82.4	99
7	1-pentanol	20.963	3	137.5	130.3
8	3-methyl-1-butanol	20.718	2.8	131	127
9	2-pentanol	20.614	2.4	119.3	121.6
10	2-methyl-1-butanol	20.847	2.6	128	125
11	3-pentanol	20.745	2.2	116.2	119.6
12	3-methyl-2-butanol	20.445	2.2	112.9	118.6
13	2,2-dimethyl-1-propanol	20.382	2.4	113.1	120.8
14	2-methyl-2-butanol	20.223	2	102.3	115.3
15	1-hexanol	24.427	3.5	157	149
16	4-methyl-1-pentanol	24.182	3.333	151.9	146
17	2-hexanol	24.078	2.833	140	139.5
18	3-methyl-1-pentanol	24.291	3.8	153	152.2
19	2-methyl-1-pentanol	24.295	3	148	142.3
20	3-hexanol	24.193	2.5	135	135.7
21	2-ethyl-1-butanol	24.391	2.833	146.5	140.6
22	4-methyl-2-pentanol	23.826	2.667	132	136.5
23	3,3-dimethyl-1-butanol	23.814	2.833	143	138.5
24	2,3-dimethyl-1-butanol	24.115	3	144.5	141.7
25	2-methyl-2-pentanol	23.663	2.333	121.5	131.8
26	3-methyl-2-pentanol	24.009	2.5	134.3	135.1
27	2-methyl-3-pentanol	24.015	2.333	129.5	133
28	2,2-dimethyl-1-butanol	23.979	2.667	136.5	137
29	3-methyl-3-pentanol	23.865	2.167	123	130.4
30	3,3-dimethyl-2-butanol	23.576	2.333	120.4	131.5
31	2,3-dimethyl-2-butanol	23.526	2.167	118.4	129.2
32	1-heptanol	27.891	4	176.4	167.6
33	5-methyl-1-hexanol	27.646	3.85	170	164.9
34	2-heptanol	27.543	3.286	160.4	157.5
35	4-methyl-1-hexanol	27.755	3.714	173.3	163.6
36	2-methyl-1-hexanol	27.760	3.428	164	160.1
37	3-heptanol	27.657	2.857	157	152.6
38	3-methyl-1-hexanol	27.739	3.571	169	161.8
39	4-heptanol	27.641	2.714	156	150.8
40	5-methyl-2-hexanol	27.551	3.143	151	155.8
41	2-methyl-3-hexanol	27.463	2.571	145.5	148.4
42	2-methyl-2-hexanol	27.127	2.714	143	148.9
43	2,4-dimethyl-1-pentanol	27.508	3.285	159	157.4
44	5-methyl-3-hexanol	27.405	2.714	148	149.9
45	3-methyl-3-hexanol	27.304	2.428	143	146

No.	Compound	ZEP	H_d.	BP (^{0}C)	
				Exp.	Calc.
46	2,4-dimethyl-2-pentanol	26.871	2.571	133.1	146.2
47	2,4-dimethyl-3-pentanol	27.282	2.428	140	146
48	3-ethyl-3-pentanol	27.487	2.286	142	144.9
49	2,3-dimethyl-2-pentanol	27.085	2.428	139.7	145.2
50	2,3-dimethyl-3-pentanol	27.161	2.286	139	143.8
51	3-methyl-2-hexanol	27.457	2.857	151	151.9
52	6-methyl-1-heptanol	31.110	4.375	188.6	183.8
53	2-octanol	31.007	3.75	180	175.7
54	3-octanol	31.122	3.25	175	169.9
55	4-methyl-1-heptanol	31.204	4.125	188	181.1
56	4-octanol	31.106	3	176.3	166.8
57	2-ethyl-1-hexanol	31.303	3.5	184.6	173.7
58	2-methyl-2-heptanol	30.591	3.125	156	166.5
59	2,5-dimethyl-1-hexanol	30.979	3.75	179.5	175.6
60	5-methyl-2-heptanol	30.871	3.5	172	172.1
61	6-methyl-3-heptanol	30.877	3.125	174	167.5
62	3.5-dimethyl-1-hexanol	30.952	3.875	182.5	177.1
63	3-methyl-2-heptanol	30.922	3.25	166.1	169.2
64	2-methyl-3-heptanol	31.155	2.875	167.5	165.4
65	2-methyl-4-heptanol	30.854	2.875	164	164.3
66	5-methyl-3-heptanol	30.979	3	172	166.3
67	3-methyl-3-heptanol	30.768	2.75	163	162.5
68	4-methyl-3-heptanol	31.028	2.875	170	165
69	3-methyl-4-heptanol	31.028	2.75	162	163.4
70	3,4-dimethyl-2-hexanol	30.838	3	165.5	165.8
71	4-methyl-4-heptanol	30.743	2.625	161	160.8
72	3-ethyl-3-hexanol	30.927	2.5	160.5	159.9
73	2,3-dimethyl-2-hexanol	30.533	2.75	160	161.6
74	3,5-dimethyl-3-hexanol	30.512	2.625	158	160
75	2,3-dimethyl-3-hexanol	30.600	2.5	158.1	158.8
76	2-methyl-3-ethyl-2-pentanol	30.611	2.625	156	160.4
77	2,4,4-trimethyl-2-pentanol	29.961	2.75	147.5	159.6
78	2,2,4-trimethyl-3-pentanol	30.407	2.5	150.5	158.1
79	2,2-dimethyl-3-hexanol	30.589	2.625	156	160.3
80	2,5-dimethyl-3-hexanol	30.675	2.75	157.5	162.1
81	4,4-dimethyl-3-hexanol	30.774	2.625	160.4	160.9
82	6-methyl-2-heptanol	30.762	3.625	174	173.3
83	3-methyl-1-heptanol	31.204	4	186	179.5
84	2-methyl-3-ethyl-3-pentanol	30.777	2.375	158	157.9
85	2,3,4-trimethyl-3-pentanol	30.456	2.375	156.5	156.7
86	7-methyl-1-octanol	34.574	4.889	206	202.6
87	2-nonanol	34.471	4.222	198.5	194
88	3-nonanol	34.586	3.667	195	187.5
89	4-nonanol	34.569	3.333	192.5	183.3
90	5-nonanol	34.569	3.222	193	182
91	2-methyl-2-octanol	34.055	3.555	178	184.3
92	2,6-dimethyl-2-heptanol	33.810	3.444	173	182

No.	Compound	ZEP	H_d.	BP (^{0}C)	
				Exp.	Calc.
93	2,6-dimethyl-3-heptanol	33.987	2.75	175	174
94	2,6-dimethyl-4-heptanol	34.065	3	174.5	177.4
95	3,6-dimethyl-3-heptanol	30.675	3	173	165.2
96	3,5-dimethyl-4-heptanol	34.410	2.778	171	175.9
97	2,3-dimethyl-3-heptanol	34.065	2.777	173	174.6
98	2,4-dimethyl-4-heptanol	33.952	2.777	171	174.2
99	2,4,4-trimethyl-3-hexanol	34.039	2.667	170	173.2
100	3,4,4-trimethyl-3-hexanol	33.932	2.555	165.5	171.4
101	4-methyl-4-octanol	35.075	2.889	180	179.7
102	4-ethyl-4-heptanol	34.366	2.667	182	174.4
103	2-methyl-2-octanol	34.055	3.555	178	184.3
104	8-methyl-1-nonanol	38.039	5.4	219.9	221.4
105	2-methyl-3-ethyl-3-heptanol	34.006	2.8	177.5	174.7
106	2-methyl-3-ethyl-1-heptanol	38.124	4	193	204.4
107	5-methyl-3-ethyl-3-heptanol	34.709	2.9	172	178.5
108	2-decanol	37.935	4.7	211	212.4
109	4-decanol	38.034	3.7	210.5	200.3
110	3,7-dimethyl-1-octanol	37.887	4.8	212.5	213.4
111	2,7-dimethyl-3-octanol	37.611	3.5	193.5	196.3
112	2,6-dimethyl-4-octanol	34.696	3.2	195	182.2
113	2,3-dimethyl-3-octanol	38.816	3.1	189	195.7
114	5-methyl-5-nonanol	37.672	3.1	202	191.6
115	4-methyl-1-nonanol	38.132	5	216	216.8
116	2-methyl-3-nonanol	37.856	3.6	200	198.5
117	2,2,5,5-tetramethyl-3-hexanol	33.952	2.9	170	175.8
118	4-propyl-4-heptanol	33.932	2.8	191	174.5
119	2,4,6-trimethyl-4-heptanol	37.160	2.9	181	187.3
120	3-ethyl-3-octanol	37.855	3.1	199	192.3
121	3-ethyl-2-methyl-3-heptanol	37.681	2.8	193	187.9
122	1-undecanol	41.748	6	245	242.2
123	2-undecanol	41.399	5.182	228	230.8
124	3-undecanol	41.514	4.545	229	223.3
125	5-undecanol	41.498	3.818	229	214.3
126	6-undecanol	41.498	3.727	228	213.1
127	1-dodecanol	45.212	6.5	261.9	260.8
128	2-dodecanol	42.035	5.667	246	239.1
129	1-tridecanol	48.676	7	276	279.5
130	1-tetradecanol	52.140	7.5	289	298.1
131	1-pentadecanol	55.604	8	304.9	316.8
132	1-hexadecanol	59.068	8.5	312	335.4

Correlations to water solubility (log(1/S)) of 60 alcohols

Aqueous solubility, S, of liquids and solids is defined as the concentration (moles per liter) of solute in the aqueous phase, at equilibrium whih a pure solute phase. This property of organic compounds is very important and widely

applied in many research areas, such as pharmaceutical chemistry, biological chemistry or environmental science.

We consider in our study a data set of 60 alcohols [17] to develop the structure-water solubility model. The experimental water solubility as log (1/S), for these alcohols, are listed in Table 2.

The simple linear correlation found is illustrated by the following equation and statistical parameters:

$$\log 1/S = -3.218 + 0.167\ ZEP;\ r = 0.972;\ s = 0.248;\ F = 992;\ N = 60; \quad (11)$$

A better water solubility point model was generated by using a two variable linear model constructed with the index ZEP and parameter H_d and is expressed by equation (12):

$$\log 1/S = -3.196 + 0.129\ ZEP + 0.337H_d;$$
$$r = 0.988;\ s = 0.164;\ F = 1175;\ N = 60; \quad (12)$$

Values of log (1/S) predicted by equation (12) are also shown in Table 2.

Table 2. Experimental and calculated log (1/S) for 60 alcohols

No	Compound	Log (1/S)		No	Compound	Log (1/S)	
		Exp.	Calc.			Exp.	Calc
1	etanol	-1.10	-1.33	31	3-heptanol	1.44	1.33
2	1-propanol	-0.62	-0.71	32	4-heptanol	1.40	1.28
3	1-butanol	-0.03	-0.10	33	5-methyl-2-hexanol	1.38	1.42
4	2-methyl-1-propanol	-0.10	-0.21	34	2-methyl-3-hexanol	1.32	1.21
5	2-butanol	-0.47	-0.31	35	2-methyl-2-hexanol	1.07	1.22
6	1-pentanol	0.59	0.52	36	2,4-dimethyl-1-pentanol	1.60	1.46
7	3-methyl-1-butanol	0.51	0.42	37	3-methyl-3-hexanol	0.98	1.14
8	2-pentanol	0.28	0.27	38	2,4-dimethyl-2-pentanol	0.93	1.14
9	2-methyl-1-butanol	0.46	0.37	39	2,4-dimethyl-3-pentanol	1.22	1.14
10	3-pentanol	0.21	0.22	40	2,3-dimethyl-2-pentanol	0.87	1.12
11	3-methyl-2-butanol	0.18	0.18	41	2,3-dimethyl-3-pentanol	0.84	1.08
12	2-methyl-2-butanol	-0.15	0.09	42	1-octanol	2.35	2.37
13	1-hexanol	1.21	1.13	43	2-octanol	2.09	2.07
14	4-methyl-1-pentanol	1.14	1.05	44	2-ethyl-1-hexanol	2.11	2.02
15	2-hexanol	0.87	0.86	45	2-methyl-2-heptanol	1.72	1.80
16	2-methyl-1-pentanol	1.11	0.95	46	3-methyl-3-heptanol	1.60	1.70
17	3-hexanol	0.80	0.77	47	1-nonanol	3.01	2.98
18	2-ethyl-1-butanol	1.01	0.91	48	7-methyl-1-octanol	2.49	2.91
19	4-methyl-2-pentanol	0.79	0.78	49	2-nonanol	2.74	2.67
20	3,3-dimethyl-1-butanol	0.50	0.83	50	3-nonanol	2.66	2.50
21	2,3-dimethyl-1-butanol	0.37	0.93	51	4-nonanol	2.59	2.39
22	2-methyl-2-pentanol	0.49	0.64	52	5-nonanol	2.49	2.35
23	3-methyl-2-pentanol	0.71	0.74	53	2,6-dimethyl-4-heptanol	2.16	2.21
24	2-methyl-3-pentanol	0.70	0.69	54	3,5-dimethyl-4-heptanol	2.51	2.18
25	2,2-dimethyl-1-butanol	0.91	0.80	55	1-decanol	3.63	3.60
26	3-methyl-3-pentanol	0.36	0.61	56	1-dodecanol	4.67	4.83
27	3,3-dimethyl-2-butanol	0.61	0.63	57	2,2-dimethyl-3-pentanol	1.15	1.12
28	2,3-dimethyl-2-butanol	0.37	0.57	58	2,2-dimethyl-1-pentanol	1.52	1.36
29	1-heptanol	1.81	1.75	59	4,4-dimethyl-1-pentanol	1.55	1.53
30	2-heptanol	1.55	1.46	60	2,2-diethyl-1-pentanol	2.42	2.36

The two-variable regression model (12) is slightly better than the two-variable regression model based on the combined use of Lu index and DAI (-OH) indices [17], which produces an model with r = 0.984 and s = 0.1807, while our model has r = 0.988 and s = 0.164. Actually, our two-variable regression model (12) is slightly better even than the three-variable regression model based on the combined use of Lu, DAI (-OH) and DAI (CH_3-) [18], which produces a model with r = 0.9876 and s = 0.1604.

CONCLUSIONS

According to the results previously presented, we conclude that the topological index ZEP based on the concept of weighted electronic distance and weighted electronic matrix CEP of the molecular graph can accurately describe the molecular structures involving heteroatoms, in this case the presence of oxigen.

The w.e.d. has the merit that it is able to differentiate not only the covalent bonds carbon-oxigen from the ones of carbon–carbon, but is also able to discriminate the covalent bonds of oxigen to a primary carbon from that to secondary or tertiary carbons. To our best knowledge, no other models have similar discrimination power for the covalent bonds with regard to their structural neighbourhood.

Two variable linear regression using ZEP and $\mathbf{H_d}$ can provide high-quality QSPR models for the two studied properties of alcohols: boiling point and water solubility.

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