STUDY OF THE EXTRACTION IN A CONTACTOR EQUIPPED WITH A NEW TYPE OF PACKING

Claudia Irina KONCSAG, Geta Simona MAIORU, Anca TOIU, Anisoara Arleziana ZAHARIA

"Ovidius" University Constanta, 124, Mamaia Bld., 8700 Constanta, ckoncsag@univ-ovidius.ro

Abstract: A new type of structured packing made of corrugated metal gauze was tested in a liquid - liquid countercurrent contactor at the extraction of some mercaptans (Ethanethiol, 1-Propanethiol and 1-Butanethiol) from gasoline with NaOH solutions (5%, 10% and 15% wt). The study was made in a laboratory installation, comparatively with the contactor without packing, acting as a dispersion column. The new packing has a great void fraction but a small specific area. However, it has sensibly better efficiency in the extraction process, proved by increasing up to 56% the mass transfer coefficients.

Keywords: *mass transfer, liquid- liquid extraction, structured packing*

INTRODUCTION

The structured packing for the extraction process can be identical to that used in mixing or in distillation processes, but previous studies [1 - 3] proved that the packing for the extraction must have a smaller specific area because of severe decreasing of the column capacity with the specific area. But decreasing the specific area has a negative effect on the mass transfer. The goal of our study was to develop a metal gauze structured packing which makes a compromise between those two effects. The new packing was

studied in the extraction of mercaptans from liquid hydrocarbon stream with NaOH, which represents an application in the petroleum refining industry.

EXPERIMENTAL

The handicraft packing studied here (Figure 1**)** was structured (made of corrugated metal gauze) and it has the following geometric characteristics: $\varepsilon = 0.98$ and $a_p = 0.60$ cm^2/ cm^3. Taking into account the small opening of the spiral, the drops are forced to detour and the tortuosity of their motion increases; as a consequence, the residence time of the drops in the column increses and the mass transfer improves.

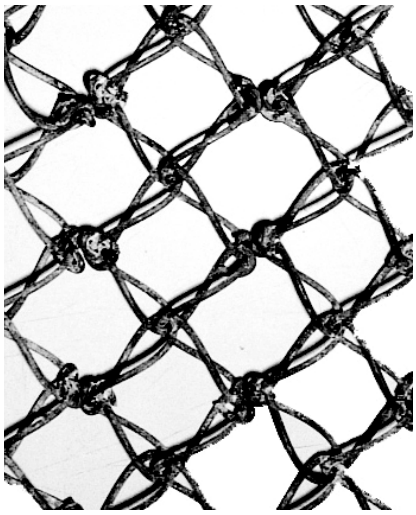

Figure 1. The structured packing

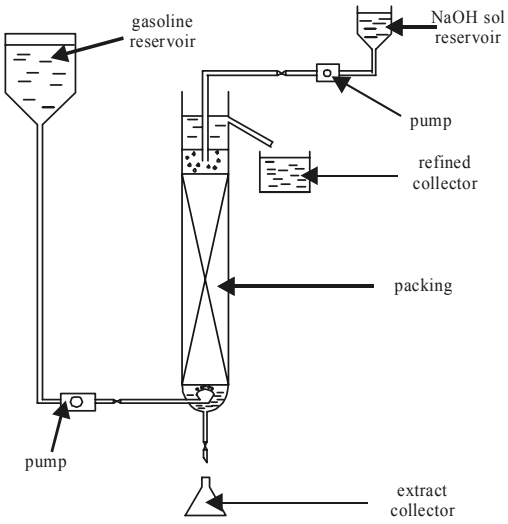

Figure 2. Laboratory installation for extraction tests

This packing was used in a laboratory installation (Figure 2). It includes a glass column with internal diameter of 3 cm and an active height of 70 cm. Two pumps assure the countercurrent flow of the phases. A glass globe with holes assures the dispersion of the light phase (the gasoline enriched with different mercaptans). The concentration of mercaptans in the feed gasoline and in the refined gasoline is found by volumetric titration with $AgNO_3$. The fresh solvents don't contain mercaptans and the concentration in the extract is found by material balance.

The experiment consisted on the extraction of different mercaptans (Ethanethiol, 1-Propanethiol, 1- Butanethiol) with NaOH solutions (5%, 10% 15% wt), at different solvent-to-feed ratios in absence and then in presence of the packing.

In a previous work [4], the equilibrium data were established and those served to the calculation of the mass transfer coefficients.

The volumetric overall mass transfer coefficients reported to the dispersed phase were calculated with the superficial velocity of the dispersed phase v_d (which is defined as the volumetric flow divided by the cross- sectional area of the column) and with the height of the mass transfer unit $[HUT]_{od}$.

$$K_{od}a = \frac{v_d}{HUT_{od}}[s^{-1}] \quad (1)$$

where the height of the mass transfer unit can be replaced from the eqn.2 which gives the correlation with the number of transfer units and the active height of the column:

$$H = [NUT_{od}][HUT]_{od} \quad (2)$$

For systems following the Nernst law and for very high values of the extraction factor ($E= K*S/A$), the number of the transfer units can be calculated from number of theoretical stages *NTT*, with the eqn. 3:

$$\frac{NTT}{NUT_{od}} = \frac{1-\frac{1}{E}}{\ln E} \quad (3)$$

The volumetric overall mass transfer coefficients (K_{od} a) were calculated in every case and the results are shown in Tables 1 - 6.

Table 1. The mass transfer coefficients at the extraction of Ethanethiol with NaOH solutions, in the dispersion column

Concentration of the NaOH solution and the repartition coefficient	**v_d, cm/s**	**x_i, ppm**	**x_e, ppm**	**y_e, ppm**	**NTT**	**NUT**	**HUT, cm**	**$K_{od}\cdot a\cdot 10^3$, s^{-1}**
5 % K=48.9	0.17	1204	662	743	0.46	1.67	41.8	2.78
	0.23		566	1118	0.54	1.85	37.8	4.31
	0.33		780	568	0.36	1.31	53.5	3.66
10 % K=92	0.17	711	188	258	0.74	3.04	23.0	5.06
	0.23		205	319	0.72	2.30	30.5	5.36
	0.33		185	458	0.75	3.51	20.0	11.67
15 % K=102.4	0.17	745	148	178	0.80	3.50	20.2	5.77
	0.23		159	223	0.79	2.76	25.4	6.43
	0.33		136	320	0.82	2.46	28.4	8.21

The data from tables 1-6 were plotted in graphs (Figures 3-5) in order to observe the effect of increasing the NaOH solution concentration, increasing the superficial velocity of the dispersed phase and increasing the molecular weight of the mercaptans.

RESULTS AND DISCUSSION

As seen from the experimental data, the mass transfer coefficients were expressed as overall volumetric coefficients related to the dispersed phase. We considered the coefficients related to the dispersed phase because it is the most common and illustrative way, as long as the transfer takes place from the dispersed phase to the continuous one [5, 6]. The coefficients were expressed as overall volumetric because

this has the advantage of avoiding the calculation of the interfacial surface, which is a difficult task because of the drops size distribution. However, the conclusions are the same for all expressions of the mass transfer coefficients.

Table 2. The mass transfer coefficients at the extraction of Ethanethiol with NaOH solutions, in the packed column

Concentration of the NaOH solution and the repartition coefficient	v_d, cm/s	x_i, ppm	x_e, ppm	y_e, ppm	NTT	NUT	HUT, cm	$K_{od} \cdot a \cdot 10^3$ s^{-1}
5 % K=48.9	0.17	1418	304	599	0.79	3.61	19.4	6.02
	0.23		544	601	0.62	2.69	26.0	6.27
	0.33		563	735	0.61	2.51	27.9	8.34
10 % K=92	0.17	337	111	243	0.68	3.88	18.1	6.45
	0.23		134	480	0.61	3.59	19.5	8.26
	0.33		35	292	0.91	4.17	16.8	13.87
15 % K=102.4	0.17	1638	487	906	0.71	4.69	14.9	7.84
	0.23		675	969	0.59	4.42	15.8	10.30
	0.33		720	1275	0.57	4.34	16.1	14.46

Table 3. The mass transfer coefficients at the extraction of 1-Propanethiol with NaOH solutions, in the dispersion column

Concentration of the NaOH solution and the repartition coefficient	v_d, cm/s	x_i, ppm	x_e, ppm	y_e, ppm	NTT	NUT	HUT, cm	$K_{od} \cdot a \cdot 10^3$, s^{-1}
5 % K=11.6	0.13	1505	865	557	0.44	1.23	56.9	1.64
	0.20		1029	563	0.33	0.83	84.2	1.66
	0.26		1068	815	0.31	0.66	105.5	1.77
10 % K=14.3	0.13	846	465	269	0.46	1.15	61.0	1.53
	0.20		568	250	0.34	0.99	70.7	1.98
	0.26		590	318	0.31	0.78	89.7	2.08
15 % K=17.7	0.13	202	66	134	0.70	1.76	39.8	2.34
	0.20		64	174	0.72	1.33	52.8	2.65
	0.26		92	192	0.58	1.02	68.4	2.73

The mass transfer coefficients at the extraction of the mercaptans with NaOH solutions decrease with the molecular weight of the mercaptans: the greatest coefficients are those at the extraction of the Ethanethiol and the smallest those, for the Butanethiol. This keeps the same trend as the repartition coefficients K, and it is normal because the value of K influences the value of the extraction factor E. The increasing of the concentration of NaOH solution has as an effect the slight increasing of the mass transfer coefficient, also according to the slight incresing of the repartition coefficient K and subsequentely, of the extraction factor E.

Table 4. The mass transfer coefficients at the extraction of 1-Propanethiol with NaOH solutions, in the packed column

Conc of the NaOH solution and the repartition coefficient	v_d, cm/s	x_i, ppm	x_e, ppm	y_e, ppm	NTT	NUT	HUT, cm	$K_{od} \cdot a \cdot 10^3$, s^{-1}
5 % K=11.6	0.13	1331	695	763	0.50	1.27	55.1	1.69
	0.20		737	977	0.48	1.08	64.6	2.17
	0.26		752	1227	0.47	0.98	71.2	2.62
10 % K=14.3	0.13	750	513	103	0.32	1.46	48.0	1.94
	0.20		501	149	0.34	1.12	62.7	2.23
	0.26		563	144	0.25	0.83	84.2	2.22
15 % K=17.7	0.13	1575	568	1739	0.68	2.14	32.7	2.85
	0.20		740	1975	0.57	2.04	34.3	4.08
	0.26		875	2133	0.48	1.48	47.3	3.94

Table 5. The mass transfer coefficients at the extraction of 1-Butanethiol with NaOH solutions, in the dispersion column

Conc of the NaOH solution and the repartition coefficient	v_d, cm/s	x_i, ppm	x_e, ppm	y_e, ppm	NTT	NUT	HUT, cm	$K_{od} \cdot a \cdot 10^3$, s^{-1}
5 % K=2.9	0.17	1149	819	127	0.30	0.70	100.6	1.16
	0.23		851	313	0.29	0.46	153.6	1.06
	0.33		931	380	0.21	0.27	256.1	0.91
10 % K=3.3	0.17	833	627	127	0.26	0.53	130.9	0.89
	0.23		619	169	0.27	0.51	136.0	1.20
	0.33		646	204	0.24	0.40	174.5	1.38
15 % K=3.5	0.17	1029	613	280	0.44	0.89	78.2	1.49
	0.23		653	323	0.40	0.75	93.7	1.74
	0.33		665	432	0.40	0.66	106.5	2.19

Table 6. The mass transfer coefficients at the extraction of 1- Butanethiol with NaOH solutions, in the packed column

Conc of the NaOH solution and the repartition coefficient	v_d, cm/s	x_i, ppm	x_e, ppm	y_e, ppm	NTT	NUT	HUT, cm	$K_{od} \cdot a \cdot 10^3$, s^{-1}
5 % K=2.9	0.17	1701	811	549	0.59	0.75	93.0	1.25
	0.25		994	309	0.44	0.57	121.8	1.43
	0.33		998	785	0.49	0.62	113.8	2.05
10 % K=3.3	0.17	996	644	246	0.38	0.94	74.6	1.56
	0.25		690	316	0.34	0.58	120.9	1.93
	0.33		696	231	0.32	1.15	60.9	2.87
15 % K=3.5	0.17	688	444	86	0.37	1.16	60.5	1.93
	0.25		378	130	0.48	0.99	70.9	2.47
	0.33		463	306	0.37	0.76	91.8	2.54

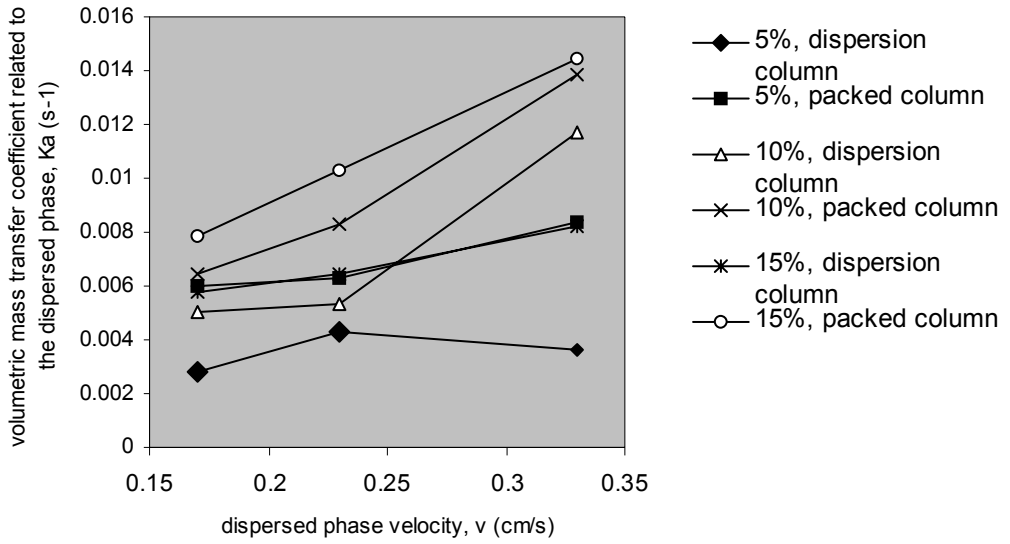

Figure 3. The mass transfer coefficients at the extraction of Ethanethiol with NaOH solutions, in the dispersion column comparatively with he packed column

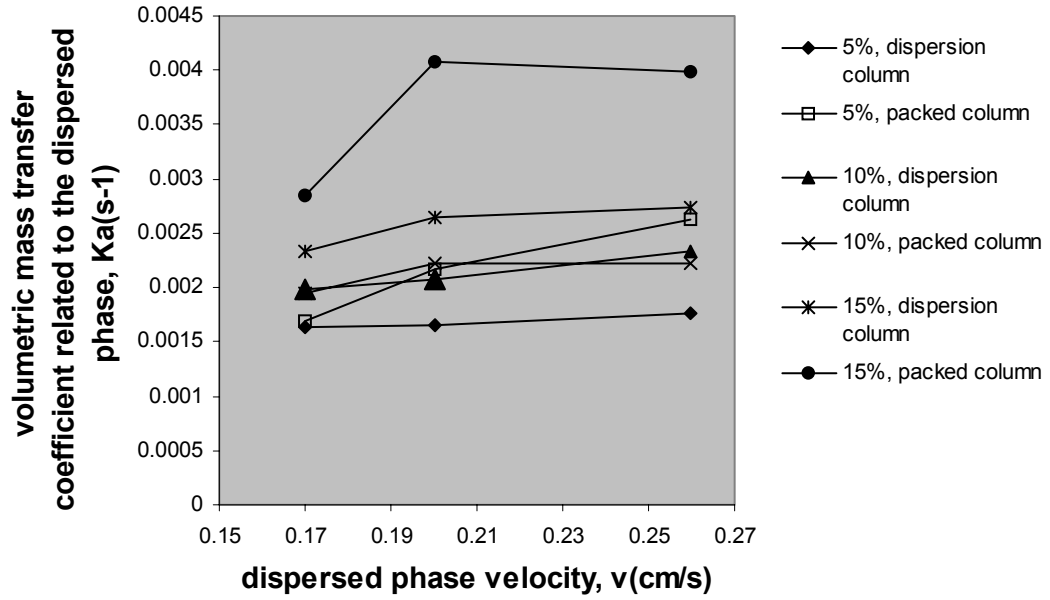

Figure 4. The mass transfer coefficients at the extraction of 1-Propanethiol with NaOH solutions, in the dispersion column comparatively with he packed column

The mass transfer coefficients increase with the superficial velocity (the linear velocity in the free cross- sectional area) of the phases. In this experiment it was considered the dispersed phase, but the same would be observed for the continuous phase. It can be explained by increasing the turbulence of the phases and by consequence, the improving of mass transfer.

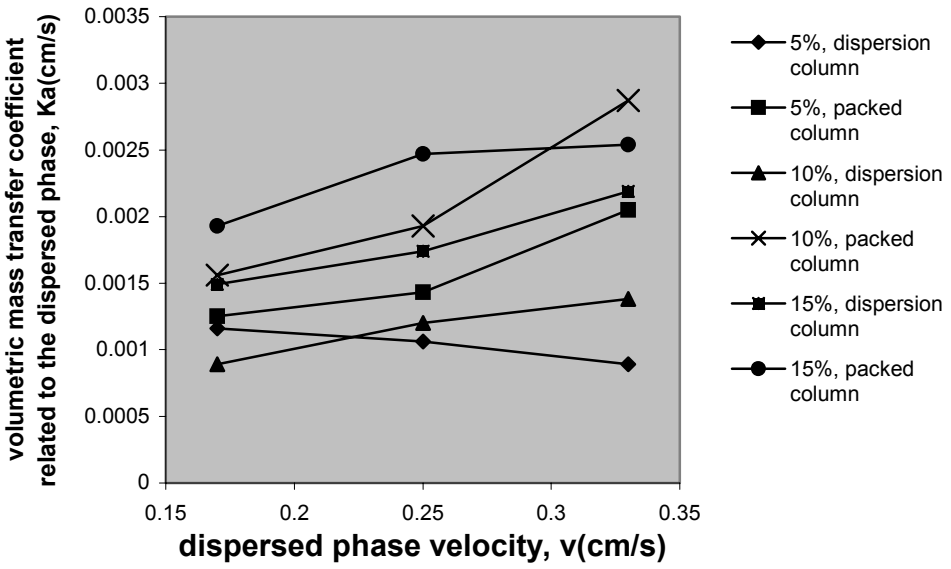

Figure 5. The mass transfer coefficients at the extraction of 1-Butanethiol with NaOH solutions, in the dispersion column comparatively with he packed column

It was interesting to observe the influence of the packing on the mass transfer: as expected, the presence of the packing leads to the increasing of the mass transfer coefficients as effect of the increasing of the dispersed phase's residence time in the column and the increasing of linear velocity of the drops. Comparing the coefficients with the case of the dispersion column, they increased up to 56% , but they are well under the values corresponding to another packing with greater specific area (3.40 cm^2/cm^3) [6].

CONCLUSION

The handicraft packing proposed here would be a good choice from mass transfer point of view but also, it is expected to play better than the packing (structured or random) with bigger specific area, because of the greater flooding capacity.

REFERENCES

1. Crawford, J.W., Wilke, C.R.: Limiting Flows in Packed Extraction Columns, *Chemical Engineering Progress*, **1988**, **47** (8),423
2. Seibert, A.F., Reeves, B.E., Fair, J.R.: Performance of a Large Scale Packed Liquid-Liquid Extractor, *Ind.Eng.Chem.Res.*, **1990, 29**, 1901
3. Koncsag, C.I.: Performances of the Structured Packing in the Liquid-Liquid Extraction Process. Hydrodynamics and Mass Transfer, *3rd International Conference of PhD Students,* **2001**, Miskolc, Ungaria
4. Koncsag, C.I., The influence of the feed and solvent quality on the mercaptans extraction from liquid hydrocarbons, *U.P.B.Sci.Bull., Series B,* **2000, 62** (3), 63

5. Laso, M., Henriques de Brito M., Bomio, P., von Stockar, U.: Liquid mass transfer characteristics of a structured packing, *Chem.Eng.J.,***1995, 58**, 251
6. Koncsag, C.I., Stratula, C.: Extractia lichid- lichid in coloane cu umplutura structurata. II. Studiul transferului de masa., *Revista de Chimie*, **2003, 54**(1), 7

Received: 09.15.2003