Utilization Potency of Extracellular Polymeric Substance as Industrials Biosorbent And Ion Exchange Resin

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Abstract :

Industrial contaminant cations and anions can be removed from water and or waste water by using ion exchange resin. Extracellular Polymeric Substances (EPS) resulting from bacteria can accumulate the elements ions from its external environment by biosorption accumulation mechanisms of adsorption, ion exchange, complex formation, and hydrogen bound. The ions exchange can accurs by supporting of negatively and positively functional groups in EPS. The EPS can be utilized as biosorbent and ion exchange resin for replacing the commercial organic ion exchange resin. The EPS is composed of polysaccharides (40-95%), protein (1-60%), nucleic acid (1-10%), lipids (1-10%), and polymers of amino acids and other compounds of microbial origin. The study of EPS utilization as biosorbent and ion exchange resin has been performed. The EPS was extracted from industrial activated sludge by 6,000 rpm centrifugation at 4^{o}C. From its analysis, the resulted EPS contains polysaccharides 60 %, protein 8 %, and lipids 16 %. The tests of resulted EPS biosorption capabilities have been done by dispersed EPS operation on the simulation radioactive liquid waste containing lead 4 x 10^4 Bq/l, uranium 4 x 10^4 Bq/l and thorium 4 x 10^4 Bq/l. The EPS performs normally the biosorption of contaminants by sequence of its selectivity i.e. Pb^{+2} > Th+4 > UO_2^{+2}. On the facts of operation result indicates that there are performance unification between the roles of selectivity and atom weight (aw) for flocculation and precipitation of contaminants in which the sedimentation sequences are Pb^{+2} (a.w 207), UO_2^{+2}(a.w 270) and Th^{+2}(a.w 232). The biosorption by dispersed EPS operation gives the supernantant water quality conforming the standards quality according to Decree of Chairman of National Nuclear Energy Agency No.02/Ka. Bapeten/V-99 (10,000 Bq/l for Pb, 1,000 Bq/l for U, and 7,000 Bq/l for Th) . On its utilization by the operation of immobilized EPS on calcium alginate (biosorbent of EPS-Ca aliginate) for removing of uranium (U) gives the sorption capacity of 881,84 mg U/g biosorbent.

Keywords: biosorption, extracellular polymeric substances, ion selectivities.

1. Introduction

The liquid waste treatment using microorganism especially the bacteria is the effective method for removing of radionuclides and heavy metals elements from the waste water by biosorption mechanism **[1]**. The biomass has the biosorption capabilities of that's elements supporting by its content of EPS **[1]**. The EPS has a complex composition consisting polysaccharides (40-95 % of total EPS), protein (1-60 %), nucleic acid (1-10 %), lipids (1-10 %), and polymer of amino acid and other compound of microbial origin **[2]**. The the EPS has to function for ion exchange due to high amount of negatively charged functional groups as carboxyl (-COOH), phosphate ($-OPO_3H$), sulphate ($-OSO_3H$), etc, and the positively charged functional groups such as hydroxyl (-OH), aminocarboxylic ($R-C(NH_2)H-COOH$) **[2]**.

Polysaccharides is the compound composing cellulose, chitin, starch, glycogen, and carbohydrate. Carbohydrate is composed of monosaccharide, maltose, lactose, sucrose, etc. The atom configuration of carbon on the polysaccharides contains the functional groups of carboxyl and hydroxyl. That's carboxyl functional group is found on the acid form of tartaric acid, aldonic acid, aldarat acid, uronic acid, gluconic acid, gulonic acid, acetic acid, ascorbic acid, sulphate on its form of $-OSO_3H$ and $-NHSO_3H$ (on the heparin structure). The polysaccharides of chitin contains the functional group of amino **[3]**.

The nucleic acid is carrier matter of genetic code on the live system, there are two types of nucleic acid i.e deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). The DNA is the long chain polymer consisting the molecule of deoxyribose-glucose being fastened on the functional groups of phosphate. Hydrolysis of DNA generates the small fractions of glucose, acid and phosphate ion. Structure of RNA is similar with the structure of DNA structure covering glucose series of ribose joining on the functional groups of phosphate. The hydrolysis of RNA generates nucleotide and nucleooxide, phosphate ion and finally ribose and alkali. The protein is polyamide compound, and its hydrolysis generates amino acids. There are 20 kinds of amino acids. On the structure of amino acids obtained functional groups of amino and carboxyl **[3]**.

The cation exchange reaction on the EPS is similar to the organic ion exchange resin as follows :

$M_1^{n+} + (EPS)_nM_2 \leftrightarrows M_2^{n+} + (EPS)_nM_1$ [1]

Where M_1^{n+} and M_2^{n+} are cations of difference species having the valence of n (n=1 or 2) in which M_1^{n+} has the greaterselectivity. The greater selectivity is the preference for ion by the exchanger. An ion exchanger tends to prefer **[4]** :

(1) ions of higher valence
(2) ions with a small solvated volume
(3) ions with greater ability to polarize
(4) Ions that react strongly with the ion exchange site of the exchanger solid, and
(5) Ions that participate least with other ions to form completes.

For the usual cation exchanger, the preference series for the most common cations are as follows **[4]** : $Ba^{+2} > Pb^{+2} > Sr^{+2} > Ca^{+2} > Ni^{+2} > Cd^{+2} > Cu^{+2} > Co^{+2} > Zn^{+2} > Mg^{+2} > Ag^{+1} > Cs^{+1} > K^{+1} > NH_4^{+1} > Na^{+1} > H^{+1}$ and $UO^{2+} >> Cu^{2+} >> Co^{2+.}$

The binding of cation by negatively functional groups of EPS is as carboxyl, phosphate, and sulphate on the ion exchange reaction are shown on the following equation :

$nR\text{-}COOH + M^{n+} \rightarrow (RCOO)_n\,M + nH^+$ [2]

$nR\text{-}OPO3H + M^{n+} \rightarrow (R\text{-}OPO3)_n\,M + nH^+$ [3]

$nR\text{-}OSO3H + M^{n+} \rightarrow (R\text{-}OSO3)_n\,M + nH^+$ [4]

The binding of anion by EPS is performed by the functional groups of hydroxyl and aminocarboxylic :

$ROH + CrO_4^{2-} \rightarrow R_2CrO_4 + 2\,OH^-$ [5]

$RCHNH_2COOH \rightarrow RCHNH_3^+COO^-$ [6]

$RCHNH_3{+}COO^- + NO_3{-} \rightarrow RCHNH_3NO_3^-\,COO^-$ [7]

$RCHNH_3NO_3COO^- + Cs^+ \rightarrow RCH\,NH_3\,NO_3COO^-$ [8]

The functional groups of aminocarboxylic can bond the anion and cation following reaction equations of 6 and 7. On the anion exchanger, the preference series for the most common anions are as follows **[4]**:

$SO_4^{-2} > NO_3^{-1} > CrO_4^{-2} > Br^{-1} > Cl^{-1} > OH^-$

The functional groups of hydroxyl, amino, carboxylic, phosphate and sulphate can also bond the metal ion to form the complex formation.

The active slugde from liquid waste treatment by biooxidation process using aerobic bacteria contains the millions of bacterial colonies. The EPS can be extracted from active sludge by solvent extraction or centrifugation. The EPS can be directly utilized by dispersion operation process or by immobilized EPS on the polymer matrix as the solid biosorbent for column operation process. The utilization of immobilized EPS has the most advantages comparing the dispersion operation i.e the operation can be performed on the reactor of packed-tower or fluidized-bed, the high loading capacity of biomass on the column, the easy separation of biomass and liquid effluent, the easy reciculation of continous operation, and the easy regeneration of saturated biomass reaching 5 time of biosorption-desorption **[1,5]**.

The capability of EPS bisorbent on the binding of radionuclides and heavy metals is interested to investigate for making utilize of the industrial active sludge. That's sludge is usually only disposed without the effort for its making use whereas it contains the EPS as raw materials for biosorbent and ion exchange. On this investigation the EPS is extracted from industrial active sludge of skin product waste treatment. The result of EPS is first tested for biosorption process by dispersion technique and then immobilized on the calcium alginate matrix.

2. Material and Methods

2.1. Material

Materials for the experiment are industrial active slugde, whatman 41 filter paper big size pore, sodium hydroxide, calcium chloride, sodium alginate, cesium nitrate, strontium nitrate, cobalt nitrate, ferrous ammonium sulfate, uranyl nitrate hexahydrate / UNH ((UO2)(NO3)2.6H2O), thorium nitrate (Th(NO3)4.6H2O), lead nitrate (Pb(NO3)2).

2.2. *Equipment*

The equipment utilizing on the experiment are pH meter, centrifuge, atomic absorption spectrophotometer (AAS).

2.3. *Method*

Preparation of Simulation Waste

The simulation waste for EPS sorption capability testing is prepared by weighing of UNH 0.21 mg, $Th(NO_3)_4.6H_2O$ 0.246 mg and $Pb(NO_3)_2$ 0.16 mg, then that's crystal are dissolved into 1 L of aquadest. The resulted simulation waste contains of uranium, thorium, and lead on the concentration of 124 mg/l (1,514 Bq/l), 210 mg/l (14,763 bq/l) and 49 mg/l (3,807.3 Bq/l) respectively. The preparation of solution pH is performed by the addition of nitric acid for decreasing of pH value or addition of soda for increasing of pH value. The simulation waste for immobilized EPS sorption capability testing is prepared by weighing of 0,19 g UNH, then that's crystal is dissolved into 1 liters of aquadest. The resulted solution contains the concentration of uranium 100 mg/l of uranium (1260 Bq/l).

Extraction of EPS from Activated Sludge

Activated sludge from industrial skin product waste treatment is filtered using filter paper with big size pore, then the resulted cake is washed using aquadest for cleaning its pollutant dirty. The clean cake is then resuspended again using aquadest on the volume of 5 times volume of cake. The new sludge is heated on 80°C during 10 minutes and then recooled until the ambient temperature. That sludge is then centrifugated on 6,000 rpm and 4°C during 20 minute. The resulted water supernatant is then filtered to clean the remaining dirty, that supernatant is the result of EPS. The solution of EPS is stored on the refrigerator. The solution of EPS is analyzed to determine the contents of polysaccharides, protein, lipids, dry-weight, and volatile dry weight.

EPS Sorption Capability Testing By Dispersed Operation

The EPS from extraction of activated sludge on the weight of 100 mg is dispersed and stired slowly on the 300 ml of simulation liquid waste containing 124 mg/l of uranium, 210 mg/l of thorium and 49 mg/l of lead on the pH 4. Every 2 hours the supernatant sample is taked, and the analyzed for determination of the concentrations of uranium, thorium and lead. The experiment is repeated for the pH of 7 and 8. The experiment is repeated for the weight of EPS 150 mg and 200 mg on the pH of solution of 4, 7 and 8.

Formation of Calcium Alginate

The solution of sodium alginate 3,75 % of weigh is dropped into the solution of calcium chloride 5 % of weigh at 4-7°C and mixed on 400 rpm at the same time during 2 hours. Result of the grain of calcium alginate is filtered and washed with aquadest, then stored on the solution of calcium chloride 2 % weigh at 4°C. Dry weigh of the grain of calcium alginate is measured.

Formation of Immobilized EPS Calcium Alginate Biosorbent

The solution containing of sodium alginate 3,75 % of weigh and EPS 1,25 % of weigh is dropped into the solution of calcium chloride 5 % of weigh at 4-7°C and mixed on 400 rpm at the same time during 2 hours. Result of the grain of EPS-calcium alginate is filtered and washed with aquadest, then stored on the solution of calcium chloride 2 % of weigh at 4°C. The dry weigh and grain diameter are measured.

Sorption Capability Testing of Immobilized EPS Calcium Alginate Biosorbent

The simulation waste containing the uranium concentration of 100 mg/l on the pH 7 is circulated on the flow rate of 1 ml/minute into adsorption column having diameter of 0.95 cm and bed heigh of 8 cm filling 6.2 g of the EPS-calcium alginate biosorbent. The sampling of recirculated solution is performed on the periode of 0, 30, 60, 120, 240 and 360 minutes for analysis of its uranium content. The experiment on the pH 7 is repeated for the flow rate of solution 3 l/minute and then 5 l/minute. The same experiment is repeated for the pH 4 and 8. The correlation data between the periode of operation v.s the uranium content on the recirculated solution is analyzed.

3. Result and Discussion.

The solution of EPS from extraction of activated sludge has the content of dry weight of 2.71 g/l, so the weigth of EPS 100 mg, 150 mg and 200 mg are equivalent of EPS solution volume of 36.9 ml, 55.35 ml and 73.8 ml respectively. The result of volatile dry weight of EPSis 1.01 g/l. For assuring that the resulted water supernatant from extraction of activated sludges is the EPS, so it is necessary to determine the EPS content of polysaccharides, protein and lipids. The analysis result of the content of carbohydrate, protein, and fat on the EPS are shown on the Table 1.

Table 1. Analysis Result of EPS Composition

No	Analyzed Component	Analysis Result (%)	Analysis Method
1.	Carbohydrate	12	Titration
2.	Protein	8	Destruction
3.	Fat	16	Gravimetry

On the Table 1, it is indicated that the percent of carbohydrate on the EPS is 12 %. The polysaccharides is organic compound composing cellulose, chitin, starch, glycogen, and carbohydrate. If it is assumed that the content of polysaccharides is 5 times the content of carbohydrate, so the percent of polysaccharides is 60 % of total EPS conforming its reference value of 40-95 %. The percent of protein on the EPS is 8 % conforming its reference value of 1-60 %. The percent of lipids is equivalent with the value for fat i.e 16 %, it is superior than its reference value of 1-10 %. That condition is compatible with the EPS origin i.e from activated sludges of industrial skin product waste treatment.

Table 2. EPS Biosorption Treatment Data For Element Of Lead (Pb)

pH	Contact time (hour)	Weight of EPS Biosorbent (g)								
		0,1			0,15			0,2		
		C (mg/l)	Efficiency (%)	q (mg/g)	C (mg/l)	Efficiency (%)	q (mg/g)	C (mg/l)	Efficiency (%)	q (mg/g)
4	0	49,14	0,00	0,00	49,14	0,00	0,00	49,14	0,00	0,00
	2	30,67	37,59	55,41	25,78	47,53	46,71	25,51	48,09	35,45
	4	23,10	52,99	78,12	19,59	60,14	59,11	20,28	58,73	43,29
	6	21,26	56,74	83,64	16,88	65,65	64,52	12,45	74,66	55,04
	8	21,87	55,49	81,81	16,14	67,17	66,01	12,65	74,26	54,74
	10	21,27	56,72	83,61	16,14	67,16	66,00	12,61	74,34	54,80
	12	21,13	57,00	84,03	16,14	67,15	66,00	12,55	74,46	54,89
7	0	49,14	0,00	0,00	49,14	0,00	0,00	49,14	0,00	0,00
	2	28,72	41,55	61,26	23,92	51,33	50,45	21,40	56,45	41,61
	4	20,22	58,85	86,76	17,67	64,03	62,93	14,50	70,49	51,96
	6	19,26	60,81	89,64	15,96	67,52	66,36	9,34	80,99	59,70
	8	19,26	60,80	89,63	14,41	70,68	69,46	9,41	80,85	59,60
	10	19,26	60,80	89,63	14,82	69,84	68,64	9,36	80,95	59,67
	12	19,27	60,79	89,62	14,75	69,98	68,78	9,88	79,89	58,89
8	0	49,14	0,00	0,00	49,14	0,00	0,00	49,14	0,00	0,00
	2	31,87	35,14	51,81	28,46	42,08	41,36	26,14	46,80	34,50
	4	25,89	47,31	69,74	22,58	54,05	53,12	17,25	64,90	47,84
	6	23,89	51,38	75,75	17,66	64,06	62,96	14,83	69,83	51,47
	8	23,23	52,73	77,73	17,87	63,63	62,54	14,79	69,90	51,53
	10	23,31	52,56	77,48	17,13	65,14	64,02	14,78	69,92	51,54
	12	23,32	52,54	77,46	17,11	65,18	64,06	14,77	69,93	51,55

Table 2 shows the relation between processing time versus the concentration of Pb on the water supernatant (c), the efficiency of Pb elimination, and biosorption capacity of Pb (q) on the pH of solution 4, 7, and 8. It is indicated that the increasing of processing time gives the decreasing of Pb concentrarion on the water supernatant. The increasing of time is equal with the raising of contact time between lead and EPS biosorbent surface for supporting lead mass transfer from the solution to EPS surface. The increasing for efficiency of Pb elimination and biosorption capacity of Pb comes from the raising of lead mass transfer. The influence of pH on the capability of EPS biosorption indicates that the pH of 7 gives the maximum result of Pb biosorption. On the utilization of 200 mg EPS and pH 7, the concentration of Pb on water supernatant is attained 9.88 mg/l (767.676 Bq/l) conforming the standard value of environmental radioactivity level on the Decree of Chairman of National Nuclear Energy Control Agency No. 02/Ka Bapeten/V-99 i.e 10,000 Bq/l for Pb. The pH 7 gives the independence condition without external influence of the lead of Pb2+ on the solution to be bound directly by negatively charged functional group of EPS. On the pH 8, the solution has the excess of negative charge inhibiting the binding of Pb2+ on the surface of EPS.

On the low pH of 4, there is the excess of positive charge on the solution causing the formation H_3O^+. The presence of H_3O^+ will covers the surface of biosorben inhibiting the biosorption mechanism of the cation of Pb^{+2} on the surface of EPS.

Tabel 3. EPS Biosorption Treatment Data For Element Of Thorium (Th)

pH	Contact time (hour)	Weight of EPS Biosorbent (g)								
		0,1			0,15			0,2		
		C (mg/l)	Efficiency (%)	q (mg/g)	C (mg/l)	Efficiency (%)	q (mg/g)	C (mg/l)	Efficiency (%)	q (mg/g)
4	0	210,20	0,00	0,00	210,20	0,00	0,00	210,20	0,00	0,00
	2	180,60	14,08	88,80	174,70	16,89	71,00	172,60	17,89	56,40
	4	167,10	20,50	129,30	154,30	26,59	83,85	150,45	28,43	89,63
	6	154,42	26,54	167,33	136,30	35,16	110,85	133,30	36,58	115,35
	8	154,51	26,49	167,06	136,31	35,15	110,83	133,51	36,48	115,04
	10	154,43	26,53	167,32	136,32	35,15	110,82	133,52	36,48	115,02
	12	154,43	26,53	167,31	136,32	35,15	110,82	133,52	36,48	115,02
7	0	210,20	0,00	0,00	210,20	0,00	0,00	210,20	0,00	0,00
	2	171,69	18,32	115,53	161,69	23,08	72,77	163,80	22,07	69,60
	4	137,90	34,40	216,90	131,80	37,30	117,60	121,90	42,01	132,45
	6	124,60	40,72	256,80	120,10	42,86	135,15	117,70	44,01	138,75
	8	124,62	40,71	256,74	117,18	44,25	139,53	115,72	44,95	141,72
	10	124,61	40,72	256,76	117,14	44,27	139,59	115,72	44,95	141,72
	12	124,61	40,72	256,77	117,17	44,26	139,55	115,72	44,95	141,73
8	0	210,20	0,00	0,00	210,20	0,00	0,00	210,20	0,00	0,00
	2	189,90	9,66	60,90	180,70	14,03	44,25	170,60	18,84	59,40
	4	171,00	18,65	117,60	159,20	24,26	76,50	149,14	29,05	91,59
	6	159,43	24,15	152,31	141,11	32,87	103,64	139,48	33,64	106,08
	8	159,31	24,21	152,66	141,12	32,86	103,62	139,48	33,65	106,08
	10	159,32	24,21	152,65	141,13	32,86	103,61	139,48	33,64	106,08
	12	159,31	24,21	152,66	141,12	32,86	103,62	139,48	33,65	106,08

Table 3 indicates the correlation between processing time to the concentration of Th on the water supernatant, the efficiency of Th elimination, and biosorption capacity of Th on the pH of solution 4, 7, and 8. It is shown that the raising of processing time gives the descending of Th concentration of water supernatant. The pH solution of 7 and the weight of EPS 200 mg is the best condition for the milieu of cations biosorption. The biosorption of Th on the EPS during 12 hours of processing time still leaves the significant remaining concentration of Th on the water supernatant of 115,72 mg/l comparing the remaining Pb concentration of 9.88 mg/l. That's condition cause of the selectivity of ion Pb^{2+} is more superior than the selectivity of Th. The influence of atom weight on that condition is not significant.

Table 4. EPS Biosorption Treatment Data For Element Of Uranium (U)

pH	Contact time (hour)	Weight of EPS Biosorbent (g)								
		0,1			0,15			0,2		
		C (mg/l)	Efficiency (%)	q (mg/g)	C (mg/l)	Efficiency (%)	q (mg/g)	C (mg/l)	Efficiency (%)	q (mg/g)
4	0	124,00	0,00	0,00	124,00	0,00	0,00	124,00	0,00	0,00
	2	109,00	12,10	335,71	99,00	20,16	207,68	96,00	22,58	152,13
	4	95,00	23,39	301,84	88,00	29,03	189,94	82,00	33,87	135,19
	6	87,00	29,84	282,48	80,00	35,48	177,03	75,00	39,52	126,73
	8	76,00	38,71	255,87	71,00	42,74	162,52	69,00	44,35	119,47
	10	74,00	40,32	251,03	71,00	42,74	162,52	69,00	44,35	119,47
	12	76,00	38,71	255,87	73,00	41,13	165,74	68,00	45,16	118,26
7	0	124,00	0,00	0,00	124,00	0,00	0,00	124,00	0,00	0,00
	2	99,00	20,16	311,52	96,00	22,58	202,84	94,00	24,19	149,71
	4	79,00	36,29	263,13	75,00	39,52	168,97	70,00	43,55	120,68
	6	73,00	41,13	248,61	70,00	43,55	160,90	67,00	45,97	117,05
	8	69,00	44,35	238,94	64,00	48,39	151,23	60,00	51,61	108,58
	10	65,00	47,58	229,26	65,00	47,58	152,84	62,00	50,00	111,00
	12	66,00	46,77	231,68	67,00	45,97	156,06	63,00	49,19	112,21
8	0	124,00	0,00	0,00	124,00	0,00	0,00	124,00	0,00	0,00
	2	114,00	8,06	347,81	104,00	16,13	215,74	99,00	20,16	155,76
	4	97,00	21,77	306,68	91,00	26,61	194,77	86,00	30,65	140,03
	6	90,00	27,42	289,74	82,00	33,87	180,26	78,00	37,10	130,35
	8	86,00	30,65	280,06	74,00	40,32	167,35	73,00	41,13	124,31
	10	86,00	30,65	280,06	73,00	41,13	165,74	70,00	43,55	120,68
	12	87,00	29,84	282,48	74,00	40,32	167,35	70,00	43,55	120,68

Table 4 shows the correlation between processing time versus the concentration of U on the water supernatant, the efficiency of U elimination, and biosorption capacity of U. It is shown that the increasing of processing time gives the decreasing of U concentration on the water supernatant. The result of that decreasing U concentration is inferior than decreasing Pb concentration cause of the selectivity degree of U less than for Pb. On the pH 7 and weight of EPS 200 mg with processing time of 12 hours, the concentration of U on the water supernatant still be 63 mg/l while the concentration of Pb is 9,88 mg/l. On the same conditions the concentration of Th still be 155,72 mg/l. The biosorption rate of Pb is superior than the rates of U and Th because the ion selectivity of Pb is the biggest. The biosorption rate of U is superior than the rates of Th because the ion selectivity of U more than for Th and molecular weight of UO_2^{2+} more than atom weight of Th.

The formation of calcium alginate gives. Its dry weigh of 24.023 mg/g, while result of EPS-Calcium alginate gives the dry weigh of 33.64 mg/g. The dry weigh of immobilized EPS on the calcium alginate matrix is 9.623 mg EPS/g matrix. The operation of column with 6.2 g biosorben EPS-calcium alginate on the variation of the flow rate of 1, 3 and 5 ml/second on the pH 4, 7 and 8 are shown an the Table 5, 6 and 7 respectively.

Table 5. Biosorption Process of Uranium (U) on the flow rate of 1 ml/minute and contact time of 0-360 minute

Contact time (minutes)	U Concentration 100 ppm, Flow Rate 1 ml/s								
	pH 4			pH 7			pH 8		
	A	B	C	A	B	C	A	B	C
0	100.00	-	-	100	-	-	100	-	
30	47.23	52.67	15.29	27.77	72.23	20.97	64.93	35.07	10.18
60	60.28	92.29	53.59	38.26	133.97	77.79	70.77	64.3	37.34
120	62.94	129.35	150.21	41.65	192.32	223.34	87.42	76.88	89.28
240	66.18	163.17	378.98	45.88	246.44	572.38	90.34	86.54	201.00
360	93.42	189.75	661.06	93.32	253.12	881.84	96.14	90.4	314.94

A : concentration of U on the effluent (mg/l)
B : concentration of absorbed uranium (mg/l)
C : the weigth of absorbed uranium (mg/g absorbent)

Table 6. Biosorption Process of Uranium (U) on the flow rate of 3 ml/minute and contact time of 0-360 minute

Contact time (minutes)	U Concentration 100 ppm, Flow Rate 3 ml/s								
	pH 4			pH 7			pH 8		
	A	B	C	A	B	C	A	B	C
0	100.00	-	-	100.00	-	-	100.00	-	
30	30.01	69.99	20.32	33.61	66.39	19.27	71.82	28.18	8.18
60	51.67	118.32	68.70	48.54	117.85	68.43	83.35	44.83	26.03
120	71.61	146.71	170.37	67.33	150.52	174.80	84.81	60.02	69.70
240	79.65	167.06	388.01	70.56	179.96	417.97	86.64	73.38	170.43
360	92.43	174.63	608.39	97.39	182.57	636.05	97.86	75.52	263.10

A : concentration of U on the effluent (mg/l)
B : concentration of absorbed uranium (mg/l)
C : the weigth of absorbed uranium (mg/g absorbent)

Table 7. Biosorption Process of Uranium (U) on the flow rate of 3 ml/minute and contact time of 0-360 minute

Contact time (minutes)	U Concentration 100 ppm, Flow Rate 3 ml/s								
	pH 4			pH 7			pH 8		
	A	B	C	A	B	C	A	B	C
0	100.00	-	-	100.00	-	-	100.00	-	
30	60.07	39.93	11.59	38.26	61.74	17.92	71.66	28.34	8.23
60	74.01	65.92	38.28	56.00	105.74	61.40	78.91	49.34	28.65
120	77.40	88.52	102.80	60.96	144.78	168.13	85.13	64.3	74.67
240	83.25	105.27	244.50	82.78	162.67	377.81	89.14	75.16	174.57
360	98.33	106.94	372.57	95.41	167.26	582.71	98.23	76.93	268.01

A : concentration of U on the effluent (mg/l)
B : concentration of absorbed uranium (mg/l)
C : the weigth of absorbed uranium (mg/g absorbent)

The cation of UO_2^{2+} and its decays daughter will be bonded by biosorbtion and ion exchange on the EPS by reaction mechanism following the equations of 1, 2, 3 and 4. According to the Tables of 5, 6, and 7, it is indicated that the increasing of operation periode gives the increasing of absorbed uranium so the biosorbent will be finally saturated. Its indicated also that the maximum of absorbed uranium is reached on the pH value of 7 comparing the pH value of 4 and 8. On the low pH, the binding of cations will decrease cause of the increasing of H+ ion concentration so EPS functional group will be covering by the association of H_3O^+. The accessibility of cations into EPS surface and pore will be inhibited by that covers. On the high pH, the EPS functional groups will suffer the deprotonisation and the formation of negatively pole accurs. The maximum of ion sorption was 881,84 mg U/g EPS-calcium alginate reaching at pH 7 and flow rate 1 ml/minute. On the flow rate of 3 and 5 ml,minute the ion sorption capacity were 636.05 and 582.71 mg U/mg EPS-calcium alginate respectively. The utilization of immobilized EPS has the most advantage comparing the dispersed EPS.

4. Conclusion

The EPS resulting from extraction of activated sludge of industrial skin product waste treatment contain polysaccharides of 60%, protein 8%, and lipids 16%. Dispersed EPS can be utilized for removal of uranium, thorium and lead from radioactive liquid waste. The result of experiment shows that the pH 7 and the weight of EPS 200 mg for treatment of 300 ml liquid waste containing 124 mg/l uranium (1514 Bq/l), 210 mg/l thorium (14763 Bq/l) and 49 mg/l lead (3807.3 Bq/l) gives the concentration of uranium, thorium, and lead on the supernatant water on value of 63 mg/l (769 Bq/l), 115 mg/l (8084 Bq/l), and 9.88 mg/l (767.676 Bq/l) respectively. That's results value of concentration already conforms to the standard value of environmental radioactivity level according to the Decree of Chairman of National Nuclear Energy Control Agency No.02/Ka-Bapeten/V-99 except for thorium i.e 1000 Bq/l for uranium, 7000 Bq/l for thorium and 10,000 Bq/l for lead. The processing time must be little extended for decreasing the result of thorium concentration on the supernatant water.

Maximum sorption capacity of UO_2^{2+} ion on the continuous column operation using 6.2 g EPS-calcium alginate biosorbent at pH 7 and flow rate of 1 ml/minute is 881.84 mg U/g biosorbent. The neutral condition gives the independency of UO_2^{2+} ion to bind directly on the negatively functional groups of EPS without the influence of external parameter. On the pH 4 there is the excess of positively charge provoking the formation of H_3O^+ ion that it will inhibit the binding of UO_2^{2+} into the biosorbent surface and pore. On the pH 8 there is the excess of negatively charge influencing the binding independency of UO_2^{2+} ion into the biosorbent surface and pore.

According to the result of experiment, the EPS-calcium alginate has the sorption capability conforming the specification of the commercial biosorbent and ion exchange resin. The immobilized EPS on the matrix has the utilization potency for replacing another biosorbent. It is necessary to investigate more on the technical and economical consideration in order to increase the economical value of activated sludge.

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