Chromium Adsorption on Neutralized Red Mud

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Red mud, the well known byproduct of Bayer process applied in alumina refineries, was extensively investigated as neutralizer and adsorbent of heavy metals from waste waters. Both red mud ion exchange capacity and ionic species adsorption specificity largely depend on its preliminary processing and chemical treatments applied to convert the raw material into useful product [1-3]. This paper reports the results of researches concerning the particularities of the adsorption process of trivalent chromium from tannery waste waters. Red mud samples were collected from the SC Alum SA Tulcea, Romania disposal pond. The preliminary treatment consists in neutralization with the following reactants: sulphuric acid (mass concentration 20%), magnesium chloride 1M, and a mixture magnesium chloride 1M and calcium chloride 1M. All the treatments have promoted the formation of new ion exchanging amorphous or crystalline phases on red mud particle surface. Adsorption studies were carried out by batch technique which yields equilibrium data, enables ion exchange capacity estimation and provides information about the residual chromium concentration in the treated effluent. The experimental data have shown the ion exchange capacity may be raised up to 60 - 62 mg/g of red mud and the concentration of chromium in the treated waters ranges between 0.03 to 0.4 mg/L. Also, it was demonstrated that above ion exchange mechanism for entrapping chromium is valid only if available chromium in waste water in contact with a given quantity of red mud is less than total chromium amount required to reach the upper limits of ion exchange capacity. Additional amounts of chromium may be physically adsorbed as chromium hydroxide gel on red mud particle surface at higher pH values, but these amounts could not be predicted when the chromium concentration in treated effluent has to be hold under some secured limits.

Keywords: chromium tannery, red mud, adsorption capacity, leaching chromium

From the rawhides currently processed in the world about ninety percents are subjected to alkaline chrome tanning, mainly due to the leather gains in mechanical strength and manufacturability. Unfortunately, the drawback of this technology stands in the poor fraction of chrome bound into the leather, which in turn brings forth high concentrations of the residual chrome in the spent tanning baths. One tone of crude wet hide averaged an amount of 50 kg of basic chromium sulphate consumption from which more than one third ends up into the waste waters beside organic matter and other debris from hide processing [1]. So far, leather wastes containing chromium (LWCC) are factually a heavy environmental burden for any tannery [2]. Several methods and procedures to handle these waste waters were reviewed [1]. Among these, chemical precipitation seems to be the most convenient way to remove at high yields the chromium compounds as $Cr(OH)_3$ under local circumstances available for step up sludge sedimentation and dewatering rates [3]. However, the tannery sludge is classified as a hazardous waste, and demands safe disposal in reliable monitored land sites [2, 4]. Even so, before landfill, some other sludge treatments are mandatory for the organic biodegradable matter removal and chromium binding into inert compounds [4]. On the other hand, the chromate leather waste processing by hydrolysis for the proteins and fats reclamation transfers the chromium compounds from waste effluents to some others composition different sludge, which disposal as a hazardous wastes is still valid [5,6]. The unwelcome incidence of transferring a heavy polluter from the waste water to landfilling sludge could be avoided, if some available alkaline waste materials could be used as collectors for Cr^{3+} ions from both solution and $Cr(OH)_3$ sludge. Such a possible collector may be the red mud coming out as byproduct from the Bayer alumina refineries [7-10]. Red mud sampled from various sources may exhibit large differences in composition as a result of the bauxite origin, technology operational parameters and yield of alumina extraction in each production unit [11]. The raw material is characterized by a high *p*H (12-12.5), high BET surface area (13-22 m^2/g), high total alkalinity (5-6 g/L), high electrical conductivity (60-350 dS/m), high ion exchangeable sodium percentage (≈100%), and poor water holding capacity [12]. Red mud remarkable acid neutralizing capacity (ANC) subsists even after apparent neutralization up to *p*H 9.0-9.5. ANC is originating not only from the total free alkalinity boarded onto the large surface of porous particles, but also from all new born solid phases which can release calcium and sodium ions very alike zeolite compounds. These new born mineralogical phases have general formula: $3(Na_2OAl_2O_3 .2SiO_2) . Na_2X$ ($X=CO_2^{2}$, $2OH^-, SO_4^{2-}, 2Cl^-$), but the representative individuals bearing ion exchange properties are: sodalite $\{Na_6[Al_6Si_6]_{24}(CO_3)_2 . 2H_2O$, cancrinite $\{NaAl(SiO_4)_6 . CaCO_3\}$, hydroxycancrinite $\{NaAl(SiO_4)_6 . NaOH . H_2O\}$ tricalciumaluminatehydrates $\{xCaO . yAl_2O_3 . zH_2O\}$, chantalite $\{CaO . Al_2O_3 . SiO_2 . 2H_2O\}$ hydrogarnet$\{Ca_3Al_2(SiO_4)_n(OH)_{12-4n}\}$ and kaolinite $\{Al_2O_3{\cdot}2SiO_2{\cdot}2H_2O\}$. Our previous works [13, 14] have revealed the large capacity of the crude red mud to neutralize acid waste waters and to adsorb heavy metals on its significantly large specific surface both by ion exchange and surface chemical reactions. Some other

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paper have disclosed certain ways to improve red mud binding capacity and stabilize its chemical composition for a safe long term landfill as non hazardous material [15-17].

Taking advantage of our previously published data concerning the red mud neutralization [13,14] and the feasible boost in rates of silicate phases crystallization on the red mud particles surface which are mainly responsible for heavy metals entrapment in their crystalline structure, this study major objective is a meaningful investigation of the Cr(III) ion adsorption on particularly chemically modified red mud adsorbent worked up through sulphuric acid, respectively magnesium and calcium salts neutralization.

Experimental part

Raw materials, reagents, additives and neutralization protocols

Red mud sampling and details of the selected neutralizing reagents as well as the neutralization protocols are described in the previous papers [13, 14]. First series of red mud neutralization was carefully carried out at room temperature by adding regularly very small quantities of sulphuric acid 20% solution into well mixed slurry under continuous pH monitoring. For the research goals the neutralization was ceased at *p*H 10.0, 9.0 and respectively 8.0, and the whole neutralized samples were stored for further chromium adsorption experiments. Beside conversion of the alkaline constituents into sulphates and their transfer to the liquid phase, other secondary reactions took place and minor amounts of silicates and aluminum silicates were decomposed with or without the reaction products washing out from solid phase along with alkali and alkali earth sulphates. To some extent our previous data [14] demonstrated that, as far as pH remains close to 8.0, no component containing calcium and silica in red mud (calcium aluminates, calcium silicates, calcium aluminum silicate, etc.) is decomposed or changed in its molar ratios against any other component. Second series of neutralization with calcium and magnesium salts was carried out at room temperature under continuous monitoring of pH up to the values 11.0 and respectively 9.0, using as reactants the 1 mol/L $MgCl_2$, $MgSO_4$ and $CaCl_2$. As was shown before [13,14], under the restriction of limited available silica for attaining normal ratios Al_2O_3/SiO_2 in common stoichiometric aluminum silicates, the calcium ions are bound preferentially as calcium aluminium silicate $\{Ca_2Al_2(SiO_4)(OH)_8\}$, and respectively hydrocalunite $\{Ca_{16}Al_8(OH)_{54}CO_3 \bullet 21H_2O\}$, and the magnesium ions are immobilized in red mud as magnesium aluminum silicate $\{Mg_{6-x}Al_x)(Si_{4-x}Al_x)O_{10}(OH)_8 . Mg(OH)_2\}$ or layered dihydroxide with general formula $[M_{1-c}^{2+} M_x^{3+}(OH)_2]^{x+} X_{x/m}^{m-} . nH_2O$, where M^{2+} = Mg or Fe, M^{3+} = Al or Fe and X^{m-} = OH-, Cl-, CO_3^{2-} or SO_4^{2-} .

Sample preparation and drying. Each properly neutralized sample was filtrated under vacuum removing the liquid phase for complementary analysis. Then, the cake was dewatered by pressing it on filter paper and repeating this procedure until less than 5% of the water was remaining behind into wet cake. Next, the red mud neutralized samples were heated progressively for 6 hours at 50°C and then to 70 °C, and subsequently dried off for 3 hours at 110°C. After cooling, the particulate samples were softly grinded to remove agglomerates and crusts and stored in sealed flasks.

Adsorption and chromium retention. Solutions of basic chromium sulphate with the concentrations in common ranging found in the tannery effluents were prepared and used for the trial runs of chromium retention on the neutralized red mud. Static adsorption and leaching tests were performed at room temperature according to recommendations of CE Directive 2003/33/CE [2]. The ratio solid/liquid in each run was 1/10 and time elapsed to reach the adsorption equilibrium was 4 h. The same parameters were used for leaching tests.

Methods of analysis. Chromium in liquid phases was analyzed by flame atomic spectroscopy using the Varian AA240FS spectrometer. Calcium and magnesium in solution were analyzed by EDTA titration, and the *p*H was measured with Consort C833 ionometer. Specific areas of the raw and neutralized red mud samples were measured with the ASAP 2020 System using nitrogen as adsorbing gas. All mineralogical phases were characterized from XRD data using Dron 2 spectrometer and semi-quantitative elemental analysis made by Philips PW2400 X-ray fluorescence spectrometer.

Results and discussion

Chromium adsorption on sulphuric acid neutralized red mud.

The first chromium adsorption tests were carried out on raw red mud with *p*H 12.6 (fig.1). Four samples encompasing chromium concentrations between 798.3 and 2395.0 mg/L have been equilibrated with raw red mud under above described conditions (table 1 and fig. 1). Results of the experiment are definitely poor, chiefly through the high concentrations of residual chromium, even if the total amounts of this metal brought by solution in the adsorption process is obviously under the red mud adsorbing capacity. Beside the higher level of the chromium in residual solution coming out from the red mud contacted for adsorption with the most diluted solutions, the leacheate released from the corresponding solid sample of adsorbent is confidently richer in chromium than the leacheate freed by samples brought in contact with more concentrated solutions of basic chromium sulphate. Factually, this is a fair evidence the red adsorption capacity dependents on *p*H, and consequently the raw product has to be finished through neutralization up to a maximum adsorption capacity. When adsorption was carried out on neutralized red mud up to *p*H 8.0 with sulphuric acid, a comprehensible descent in slope of chromium concentration in the residual solutions was observed, as the chromium concentrations in the initial chromium solution are lower and lower. Additionally, figure 2 exibits the plain raise of the cromium concentrations in the charge red mud after the contact with incoming more and more

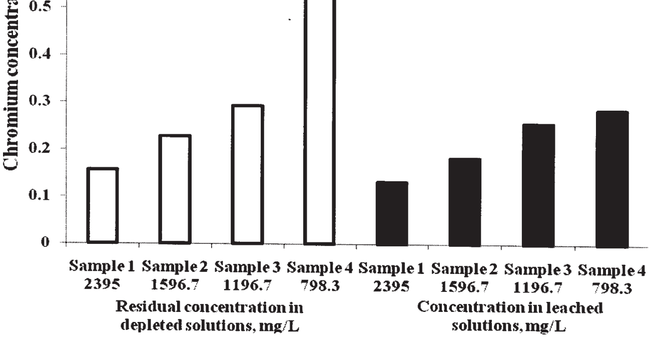

Fig. 1. Chromium concentation in the depleted solution and in the chromium leachate I; Raw red mud with *p*H 12.6

Table 1

INITIAL CHROMIUM CONTENT THE ADSORPTION TESTS SOLUTIONS AND IN THE SUPPLEMENTARY TEST LEACHATES

Samples	Chromium concentration	
	In initial samples, mg/L	In supplementary leachates, µg/L
Sample 1 - 1710	1,710	
Sample 2 - 1370	1,370	
Sample 3 - 1030	1,30	
Sample 4 - 680	0,80	
Sample 5 - 340	0.340	
Sample 3 - 1030	-	Leachate I : 0 Leachate II : 14 Leachate III :13
Sample 4 - 680	-	Leachate I : 40 Leachate II : 972 Leachate III :1973

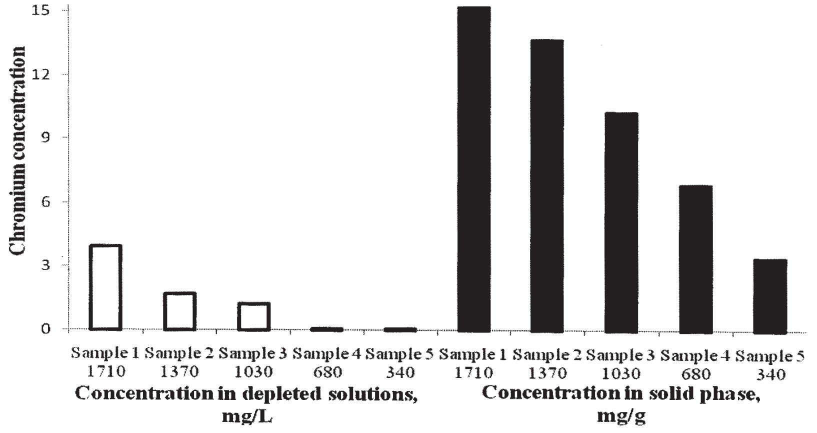

Fig. 2. Chromium adsorption on sulphuric acid neutralized red mud at pH 8.0. Chromium concentration in the purified solution and in the chromium concentration in adsorbent

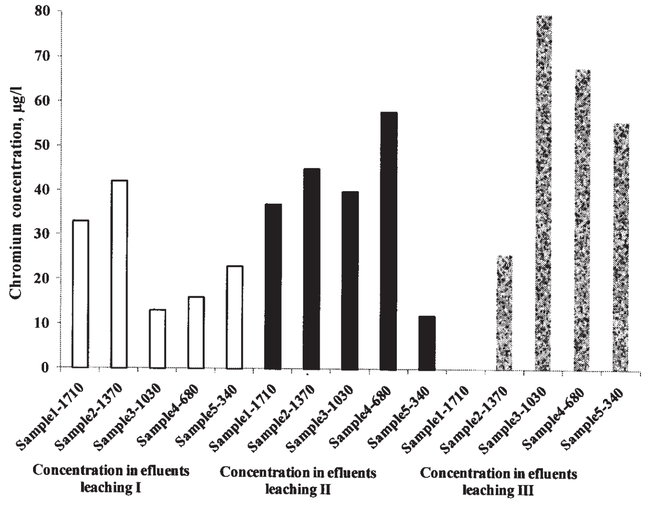

Fig. 3. Chromium concentation in the leachate I, leachate II and leachate III. Red mud neutralized with sulphuric acid up to pH 8.0

concentrated solutions. The above series of chromium adsorption experiments on neutralized red mud was coupled with the charged red mud leaching evaluation on the basis of three succesive extractions from the samples containing chromium at the levels given in figure 2. Results of the experiments are ploted in the figure 3. All the samples are releasing specific leachable parts of chromium adsorbed on the neutralized red mud turning out the leachates with chromium concentrations in the usual range of the heavy metals leaching yields from some common adsorbents. Hence, the small concentration of chromium in leachates (ranging between 10 and 70µg/L) may substantiate the findings about functional interdependence between the adsorption capacity and the achieved neutralization degree in red mud [18, 19]. Each leach brings on significantly different data, but the questionable accuracy in measuring such small concentrations should be considered (fig. 3). Thus, the strength of chromium bonds on the red mud surface has to be verified by further experiments. One way to get more facts is another leaching test performed on the samples of red mud which already have been passed through the initial three leaching runs. Only because the samples 3 and 5 have given the major scatterings results over the first three leachings, they were chosen for a supplementary leaching test. Sample 3 was again leached for three times at *p*H 3.5 and sample 5 went for another 3 leaches at *p*H 5.0. The data out of this supplementary test are given in table 1. According to the table 1, the runs on sample 3 have proved the same leaching potential as the previously ones, but sample 4 stepped up the releasing rate many times at each new leach and behaved like a metastable composition under slow but steadily dissolution. Therefore, red mud sulphuric acid neutralization produces relative poor quality adsorbents, which can be used only for chromium removal from chromium contaminated effluents with a further mandatory processing for the adsorbed chromium reclamation. Consequently, sulphuric acid neutralized red mud is not a quite reliable safe adsorbent for heavy metals landfilling, and definitely the chromium charged material could not be landfilled in storage sites as non hazardous material.

Chromium adsorption on alkali earth metal salts neutralized red mud

Calcium and magnesium salts may neutralize the red mud in a uncommon peculiarly way due to their capacity to precipitate/crystallize gipsite from diluted aluminate solutions as well as, silica and other constituents from all the solid metastable phases, bonding them as insoluble aluminate and aluminate silicate new compounds with

Table 2
SAMPLE PREPARED FOR THE SURFACE AREA MEASUREMENT

Sample code	Neutralizant	pH
RM	No	12.6
Ca pH 11.0	$CaCl_2$1M	11.0
Ca pH 10.5	$CaCl_2$1M	10.5
Mg1 pH 11.0	$MgCl_2$1M	11.0
Mg1 pH 9.0	$MgCl_2$1M	9.0
Ca+ Mg1 pH 11.0	$CaCl_2$1M + $MgCl_2$1M	11.0
Ca+ Mg1 pH 9.0	$CaCl_2$1M + $MgCl_2$1M	9.0
Mg2 pH 11.0	$MgSO_4$1M	11.0
Mg2 pH 9.0	$MgSO_4$1M	9.0
Ca+ Mg2 pH 11.0	$CaCl_2$1M + $MgSO_4$1M	11.0
Ca+ Mg2 pH 9.0	$CaCl_2$1M + $MgSO_4$1M	9.0

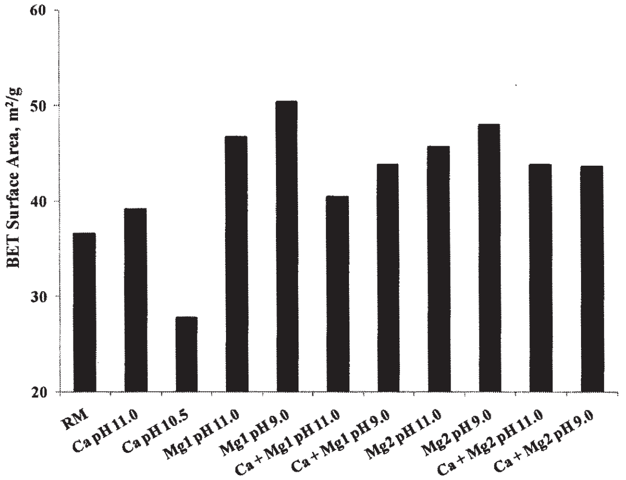

Fig. 4. BET surface area of the red mud neutralized with calcium and magnesium salts

metallic ions capture in ion exchangeable positions. It was demonstrated that all alkali earth salts neutralizing systems over the advanced stages of neutralization have produced new born solid phases carrying high specificity for heavy metal adsorption and entrapping [14]. Beside ionic exchange phases, the availability of the metastable bound calcium, magnesium and alumunum hydroxides in the neutralized red mud prove the prospect of eventual bonding of chromium bonding during its adsorption process. There were carried out three series of experiments to demonstrate the capacity and performances of the neutralized red mud as adsorbent of chromium from solutions originating from basic chromium sulphate. Mainly, the tested products were red mud neutralized with $MgCl_2$ 1M solution at *p*H 9.0 and 11.0 and red mud neutralized with $MgCl_2$ and $CaCl_2$ 1M solutions at *p*H 9.0 and 11.0. Series 1 concerns the measurements of specific surface area for typical samples of neutralized red mud with alkali earth metal salts. Series 2 comprises adequate adsorption experiments from solutions with variable concentration in Cr^{3+} and variable solid –liquid ratios aiming for an accurate measurement of ion exchange capacity. Series 3 encompasses standard leaching test over the chromium charged samples carried at variable chromium charges in neutralized red mud. Samples prepared for surface area measurements were carefully processed in order to reach the advanced water removal without chemical changes in solid mineralogical phases structure and distribution. Sample codification is given in table 2 and the results of measurements in the figure 4. Except sample neutralized with $CaCl_2$ 1M solution, all the other samples have larger surface area than the raw red mud. Apparently, the area extension seems to be independent of *p*H, so far the pH does not slope lower than *p*H 9.0. Actually, the new born phases are precipitating slightly below *p*H 11.0, but they are really separated and eventually crystallized down to *p*H 8.0-9.0. During the sample preparation for measurement, the heating and over drying might accelerate the mineralogical phases crystallization and conversion to other chemical compound. These changes may alter particle surface and hide the real surface area dependency on *p*H. Anyway, magnesium sulphate and magnesium chloride neutralization extends the red mud surface area with 75 and respectively 85% which clearly suggests a similar increase in ion exchange capacity. Adsorption test was initially set up to provide reliable data on chromium equilibrium concentration in solutions contacted with

Table 3
CHROMIUM ADSORPTION ON RED MUD NEUTRALIZED WITH $MgCl_2$ SOLUTION at pH 6.0

Sample code	Ratio Liquid/ solid	Chromium initial concentration, mg /L	Exit concentration, mg / L	Available chromium in solution, mg /g RM	Chromium charge in adsorbent, mg / g NR	Adsorption yield, %
L1.1A	10	32.625	0.131	0.326	0.324	99.60
L1.2A	20		0.224	0.652	0.648	99.31
L1.3A	40		0.202	1.305	1.297	99.38
L1.4A	80		0.130	2.610	2.599	99.60
L2.1A	10	165.2	0.515	1.652	1.646	99.69
L2.2A	20		0.366	3.304	3.296	99.78
L2.3A	40		0.177	6.608	6.600	99.89
L2.4A	80		0.077	13.216	13.209	99.95
L3.1A	10	318.1	0.512	3.181	3.175	99.84
L3.2A	20		0.273	6.362	6.356	99.91
L3.3A	40		0.075	12.724	12.721	99.98
L3.4A	80		0.096	25.448	25.440	99.97
L4.1A	10	1357.4	0.133	13.574	13.572	99.99
L4.2A	20		0.956	27.148	27.128	99.93
L4.3A	40		110.825	54.296	49.863	91.84
L4.4A	80		471.300	108.590	70.888	65.28
L5.1A	10	3210	0.663	32.100	32.093	99.98
L5.2A	20		75.675	64.200	62.686	97.64
L5.3A	40		635.100	128.400	102.996	80.21
L5.4A	80		1938.500	256.800	101.720	39.61

Table 4
CHROMIUM ADSORPTION ON RED MUD NEUTRALIZED WITH $MgCl_2$ 1M + $CaCl_2$ 1M SOLUTION at pH 9.0

Sample code	Ratio Liquid/solid	Chromium initial concentration, mg / L	Exit concentration afer adsorption, mg / L	Available chromium in solution, mg / g RM	Chromium charge in adsorbent, mg / g NR	Adsorption yield, %
L1.1B	10	32.625	0.053	0.326	0.325	99.84
L1.2B	20		0.069	0.652	0.651	99.79
L1.3B	40		0.068	1.305	1.302	99.79
L1.4B	80		0.059	2.610	2.605	99.82
L2.1B	10	165.2	0.184	1.652	1.650	99.89
L2.2B	20		0.135	3.304	3.301	99.92
L2.3B	40		0.072	6.608	6.605	99.96
L2.4B	80		0.030	13.216	13.213	99.98
L3.1B	10	318.1	0.194	3.181	3.179	99.94
L3.2B	20		0.120	6.362	6.359	99.96
L3.3B	40		0.052	12.724	12.721	99.98
L3.4B	80		0.171	25.448	25.434	99.95
L4.1B	10	1357.4	0.062	13.574	13.573	100.00
L4.2B	20		1.398	27.148	27.120	99.90
L4.3B	40		112.975	54.296	49.777	91.68
L4.4B	80		419.100	108.592	75.064	69.12
L5.1B	10	3031	2.564	30.310	30.284	99.92
L5.2B	20		108.050	60.620	58.459	96.44
L5.3B	40		839.750	121.240	87.650	72.29
L5.4B	80		2178.500	242.480	68.200	28.13

variable chromium charges in the neutralized red mud. To the extent of this purpose 5 solutions containing between 0.32 and 3.20 g/L Cr^{3+} as chromium basic sulphate were prepared and mixed with neutralized red mud at solid/liquid variable mass ratios from 1/10 to 1/80. Some ratios were deliberately chosen to overpass significantly the adsorption capacity of red mud. Equilibrium data were computed from total chromium analysis in both initial and depleted solutions. Raw data are given in the tables 4 and 5. From the entire rows of the chromium concentrations in equilibrated solutions after adsorption, there were chosen only the ones bearing the *p*H 7.0±0.5. Each chosen solution in table 3 and 4 has corresponding pair values of available chromium in solution and chromium charge in adsorbent.

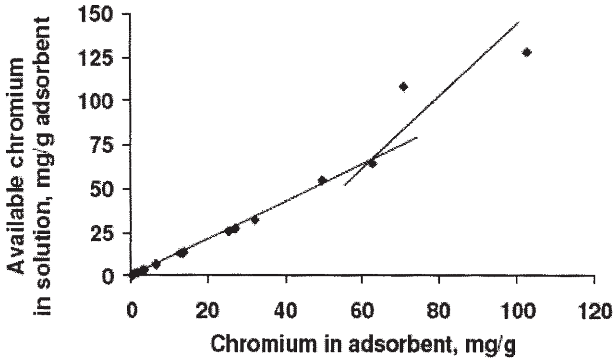

Fig. 5. Available chromium in solution versus the chromium charge in the red mud neutralized with $MgCl_2$ 1M solution

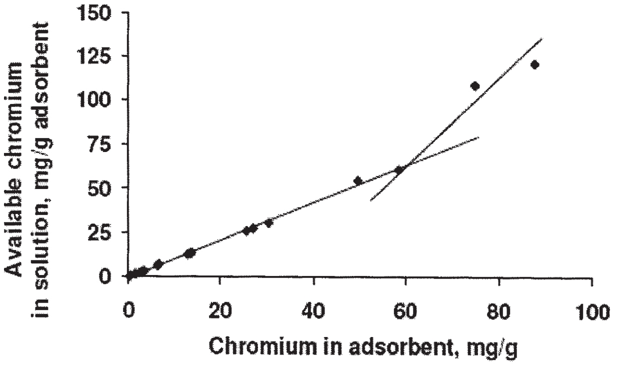

Fig. 6. Available chromium in solution versus the chromium charge in the red mud neutralized with $MgCl_2$ 1M + $CaCl_2$ 1M solutions

These pairs of values have served for graphical plot of available chromium in solution versus chromium charge in adsorbent in figures 5 and 6. Since the left linear correlation line stands for adsorbent saturation with chromium ions, and the right linear correlation line depicts the random adsorbent oversaturation beyond the breakthrough of adsorption capacity. The intersection point where the available amount of chromium per gram of adsorbent equals the adsorbed amount of chromium rates the neutralized red mud absorption capacity. Figures 5 and 6 are clearly showing the absorption capacity lays close to 60 mg/g, without significant differences between the two adsorbents. Since the ion exchange compounds in the neutralized red mud adsorbents are quite the same and also between their specific surfaces there are minimal differences the result seems to be fair reasonable. Above all, the chromium concentration in the depleted solutions up to the adsorbent charge capacity is under the reasonable admitted levels for industrial released effluents (table 3 and 4). Furthermore improvements on this side of adsorption process on red mud may come from better pH control of influent solutions before adsorption. Main adsorption process performances have been evaluated over the same data from table 3 and 4). Figure 7 and 8 are collecting the following information concerning: chromium

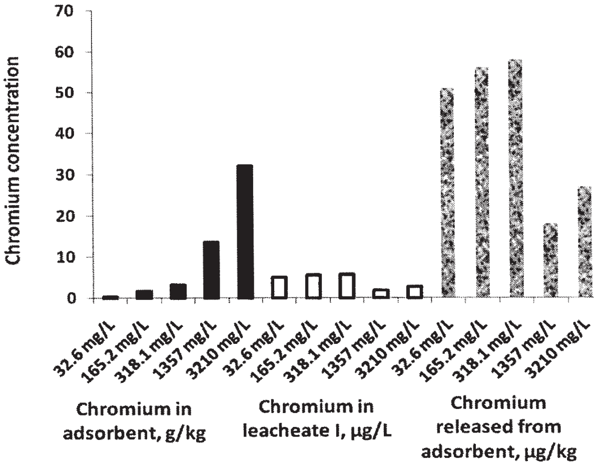

Fig. 7. Adsorption performances of the red mud neutralized with $MgCl_2$ 1M solution

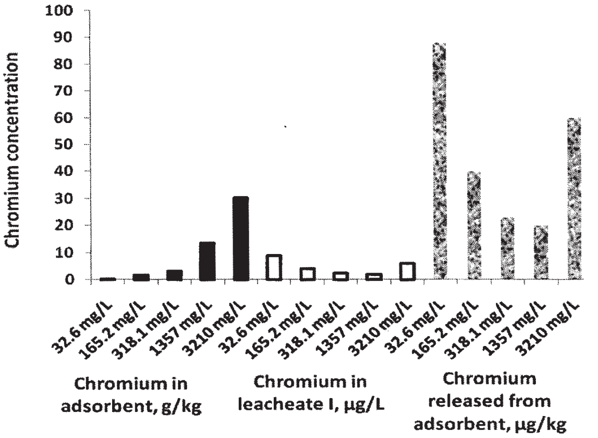

Fig. 8. Adsorption performances of the red mud neutralized with $MgCl_2$ 1M and $CaCl_2$ 1M solution

accumulated in adsorbent (mg/g),chromium concentration in first leachate (μg/L) and chromium released from adsorbent during first leaching (μg/kg) for the same row of influent solutions and for the both type of adsorbents. According to the above mentioned figures, when only half of the adsorbing capacity is employed, the residual chromium concentration in depleted solution lays around less than10 μg/L. Also, the leachate conveys 40 to 80 μg of chromium per kg of adsorbent, which accounts for less than 0.3x 10^{-3} % from total adsorbed chromium. These figures place the neutralized red mud among the best adsorbents of chromium from residual waters.

Conclusions

This experimental study major objective was the study of Cr(III) ion adsorption on particularly samples of chemically modified red mud finished through sulphuric acid, respectively magnesium and calcium salts treatment. Red mud sulphuric acid neutralization produces some poor quality adsorbents, which can be used only for chromium removal from chromium contaminated effluents accompanied by a further mandatory processing for the chromium reclamation as chromate. Consequently, sulphuric acid neutralized red mud is not a quite reliable safe adsorbent for heavy metals and definitely could not be landfilled in storage sites as non hazardous material when it is charged with chromium.

Three series of experiments were carried out to demonstrate the capacity and performances of the neutralized red mud as adsorbent of chromium from solutions originating from basic chromium sulphate. Mainly, the tested products were: a) red mud neutralized with $MgCl_2$ 1M solution at *p*H 9.0 and 11.0 and b) red mud neutralized with $MgCl_2$ and $CaCl_2$ 1M solutions at *p*H 9.0 and 11.0.The experiments have been fairly backed up the unambiguous existence of high ionic exchange capacity phases like hydrotalcite carbonate, hydrotalcite sulphate and hydrocalunite in the red mud neutralized with magnesium and calcium salts. Beside ionic exchange phases, the availability of the metastable bound calcium, magnesium and alumunum hydroxides in the neutralized red mud proves the prospect of eventual bonding of chromium by further adequate processing. Accordingly, when only half of the adsorbing capacity (about 60 g/kg adsorbent) is employed, the residual chromium concentration in depleted solution lays to values less than 10 μg/L. Also, the leachates convey 40 to 80 μg of chromium per kg of adsorbent, which accounts for less than 0.3 x 10^{-3} % from total adsorbed chromium.

Adequate neutralization process parameters (aluminate content, reactant concentrations, neutralization rates, temperature,etc.) improve the adsorbent performances and frame their properties to some quality reproducible standards. Thus, if the neutral red mud adsorbent qualities are required, fresh red mud rich sodium aluminate is highly recomended to be selected and processed for this porpose. If the neutralization process is practiced to yield a non hazardous material to be safely dosposed, then the wheathered red mud is recomended to be selected for convenient neutralization process.

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Manuscript received: 27.04.2009