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Study the Effect of Rice Husk Ash on Durability of Cemented Radioactive Waste Block

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Abstract

The aim of this work is to investigate the usage of rice husk ash in improving the properties of Portland cement which used in solidification of radioactive waste. Untreated and Potassium Hydroxide (KOH)-treated rice husk ash loaded with Cobalt, Strontium and Cesium were fixed on ordinary Portland cement. In the present study, Cobalt, Strontium and Cesium ions were used instead of Cobalt, Strontium and Cesium isotopes because the chemical behavior of the metal ions is similar to radioisotopes. Mechanical properties, effect of temperature on the compressive strength and leaching behavior of the final solid waste block had been studied. The results obtained showed that the compressive strength increases by an increasing amount of additives added for untreated rice husk ash, but decreases for KOH treated rice husk ash blocks. Infrared analysis (IR) and Thermogravimetric analysis (TGA) were performed. Effect of contact time and initial concentration on the leaching process using distilled water and underground water as leachants had been investigated. The results showed the effective use of ordinary Portland cement in solidifying and stabilizing radioactive waste and using rice husk ash as substitution cementing material is effective in enhancing the properties of cemented radioactive waste matrices

Key words; Portland cement ; Radioactive waste; Rice Husk ash; Compressive strength; Leaching.

1. Introduction

Radioactive wastes are produced as a result of different nuclear fuel cycle activities or as a result of the use of radio isotopes in the various applications e.g. medicine, agriculture and in scientific research. These wastes are so hazard to the environment and public health; thus it must be managed in a safe manner. Solidification of radioactive wastes is very important in the management process. Radioactive wastes such as concentrated wastes, spent resins, dry active wastes and sludges must be homogeneously solidified to govern the release of radionuclides [1]. The immobilization of radioactive wastes in cemented blocks can be done via two simultaneous processes, which are stabilization and solidification. The first process used to reduce the mobility of radio-contaminants, and the second one used to improve the mechanical performance of the produced waste form [2]. Immobilization of radioactive wastes using cement is most practiced to immobilize low and intermediate level radioactive wastes. Cement can be used for the solidification of radioactive wastes due to its chemical, radioactive and thermal stability. Portland cement is most commonly used for the solidification of Low and Intermediate level waste [1]. The solidification of contaminated materials by cement includes three aspects: (a) physical adsorption of the contaminants on the surface of hydration products of the cement, (b) physical encapsulation of contaminated waste or soil and (c) chemical fixation of contaminants–chemical interactions between the hydration products of the cement and the contaminants. The (a) and (c) aspects depend on the nature of the hydration products and the contaminants, and (b) aspect relates to both the nature of the hydration products and the pore structure characteristics of the paste [3]. One of the disadvantages of cemented waste blocks are their porosity which in aqueous media lead to the release of radionuclides to the environment, so additives have been used as effective techniques to improve the properties of such blocks [4].

Compressive strength is an important factor for the mechanical stability of the final solid waste block. Supplementary cementitious materials are proved to be effective in getting a durable concrete such that

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blended cements are now used in many parts of the world. When the pozzolanic material blended with Portland cement**,** Calcium Hydroxide [$Ca(OH)_2$] which is obtained as one of the hydration products of ordinary Portland cement, this material reacts with the $Ca(OH)_2$ to produce an additional calcium-silicate-hydrate (C-S-H) gel, which is the main cementing component. So the pozzolanic materials used to reduce the quantity of the harmful $Ca(OH)_2$ and increase the quantity of the beneficial C-S-H. It is observed that the immobilizing quality is enhanced if a good pozzolanic material is blended in suitable quantity with OPC [5-6].

Previous studies showed that when pozzolanic material and cement are blended it results in higher sulfate resistance, improved durability and obvious economic benefits [7].

Several researches have focused on the use of different ash materials as supplementary cementing materials such as, coal power plant ash and agricultural ash (rice husk ash (RHA), rice straw ash, etc.) [8-13].

Rice husk which is generated during de-husking of paddy rice, in many countries is used as biomass fuel or as bulking agents for composting of animal manure. The high silicon content of rice husk ash makes it more desirable to be used for partially replacement of ordinary Portland cement (OPC) in low-cost concrete for rural housing [14].

Rice husk ash can be used as an alternative cementitious binder due to the high pozzolanic activity and strong heavy metal sorption property [15]. The quality of the different kinds of silica compounds of rice husk ash depend on the burning time and temperature. Sintered RHA has two silica forms: crystalline and amorphous. When rice husk is sintered at temperature ranging between 500 oC and 900 oC, the heat transforms the silica compounds into approximately 90% amorphous silica, but when the sintering temperature exceeds 900 oC, the silica compounds convert to crystalline form, which is not suitable for OPC materials [16-17]. The performance of concrete by adding rice husk ash as a partial replacement material of cement is being improved and also improves some properties of concrete, such as corrosion resistance, strength and resistance to chloride ion penetration [17-18].

The presence of rice husk ash in cemented materials leads to the improvement of the physical and the chemical properties. Rice husk ash as much as 20% has been used to replace cement in the treatment of sediment contaminated with Cr, Cu and Pb [19]. Addition of rice husk ash to concrete help in producing a durable concrete. The results of the pozzolanic reactions between calcium hydroxide produced from the cement hydration and the amorphous silica of rice husk ash formed Calcium-Silicate-Hydrates. This gel fills the voids between the cement grains, so it reduces the number of large pores and also increases the probability of transforming the continuous pores into discontinuous ones. The compressive strength of concrete containing rice husk ash depend on the water-cement ratio, but at least up to 10% cement replacement with rice husk ash will result in strength enhancement compared with the control specimens [20].

Rice husk ash could be used as supplementary cementing material up to a certain level of replacement (about 20-30%) without decreasing the strength of concrete. Proper consumption of these rice husk ash contributes in production of cost-effective concrete and solving environmental pollution. It can also play an important role for the production of sustainable concrete [21].

Leaching can be defined as the diffusion of radioactive ions into outer medium by conjoint pores. Leaching rate of contaminated materials can be determined by the properties of the waste form such as water content, pore structure, hydraulic conductivity and homogeneity. Many researches done to investigate the relations between the microstructure of the solidification products and ions leaching. These researches showed that reducing pores in solidification products and improving pore structures are effective methods in order to mechanically contain wastes in solid [22]. Integration of pozzolanic materials into Ordinary Portland cement leads to the formation of stable calcium silicates, predominantly introduced to strengthen the structure of C-S-H gel which exhibits fundamental cementitious properties. The formation of calcium silicate hydrate via hydration of OPC help in enhancement of the efficiency in minimizing leachability of heavy metals [23]. The leaching of cesium from cemented waste matrix represents an important challenge for scientists. This is due to the low sorption potential of cement toward cesium, Therefore, several researches have been carried out on this issue [23]. The cementation using rice husk ash as pozzolanic material can be applied for strontium waste immobilization [24]. The aim of this work is to investigate the usage of rice husk ash in two forms (untreated and KOH treated) in improving the properties of Portland cement which used in solidification of radioactive waste.

2. Experimental

2.1. Materials

Double water still purifying system (model Saat 8D) was used for supplying double distilled water. Ordinary Portland cement used in this work is from **Cemex Egypt** company. Potassium Hydroxide (KOH) scales, Cobalt Chloride ($CoCl_2 .6H_2O$), Strontium Chloride ($SrCl_2 .6H_2 O$) and Cesium Chloride (CsCl) scales used are from **EL Nasr** pharmaceutical chemicals company. Rice husk ash was obtained by burning rice husk in electric furnace for 6 hours at temperature ranging from 550 to 600 ºC. Ground water used was from well no # 202 at Inshas site and the chemical composition of underground water used in this study is shown in table1 [25].

Table 1: Chemical composition of underground water.

Element	Conc.(mg/l)
Ca^{+2}	74
Mg^{+2}	13
Na^{+}	149
K^{+}	23
HCO_3^{-}	272
SO_4^{-2}	317
Cl^{-}	137

2.2. Preparation of cemented waste block

For preparing KOH treated RHA, 1M of KOH solution was prepared by dissolving 56.11 gm of KOH scales in 1000 ml of distilled water. The treated species soaked for a week at room temperature then being filtered by filter paper and rinsed by 500ml of tap water twice and being dried at 160 ºC for 6 hours then drilled to size of 3mm and stored in plastic containers. 1 gm of Cobalt-rice husk ash, Strontium-rice husk ash and Cesium-rice husk ash was manually mixed with 70 gm of ordinary Portland cement and 30 gm water and cylindrical samples of diameter 5cm and thickness of 1cm were prepared and left for 1month. Leaching test has been performed on these samples and solid blocks were suspended in leaching containers. The whole surface area of the solidified block was exposed to the immersion medium and the leaching solution surrounded the samples with equal depth from all sides. The leachant volume was 200 ml and kept constant in all the work. The investigations for leaching behavior carried out using distilled water and underground water. The Cumulative leaching percent has been calculated using equation (1) which is:

Cumulative leaching percent = $A/A_o * 100$ (1)

A: Concentration of metal ion leached at different contact time and different concentrations in ppm

A_o: Initial concentration of metal ion used in ppm [4]

2.3. Compressive strength

The compressive strength for the prepared samples was carried out using Power Pack Compression Testing Machine figure (1) for three times and average values is calculated. Three weights from rice husk ash (1g, 2g, and 3g) were immersed onto Portland cement and the compressive strength has been investigated. The compressive strength has been calculated using equation (2):

Stress = force/area = F/A (N/cm^2) (2)

Where

F: Loaded force on specimen, (Newton).

A: Area of specimen, (Cm^2)

Figure (1): Power pack Compression testing machine.

2.4. Fourier Transform Infrared Spectroscopic Analysis (FTIR)

IR spectroscopy can be used to recognize the functional groups present in the materials used in this work (untreated, KOH treated). The infrared spectra was done using an FT-IR spectrometer (Bruker, Unicom, Germany in the range of 400-4000 cm^{-1}).

2.5. Thermogravimetric Analysis (TGA)

The TGA thermograms of the investigated samples were carried out using shimadzu-50 instrument (Kyoto.Japan) at a heating rate of 10 ºC /minute under flowing nitrogen (20 ml/min) from room temperature to 600 ºC.

2.6. Atomic Absorption Spectrophotometer Analysis

The quantitative determination of Cobalt, Strontium and Cesium ions were carried out using atomic absorption spectrophotometer (Buck) model 210 VGP with element hallow cathode lamps at wavelengths 240.7, 460.7 and 852.1nm respectively.

3. Result and Discussions

3.1. Compressive strength

The effect of additives weight on the compressive strength of cement samples contain untreated rice husk ash and KOH treated rice husk ash are shown in figure (2). From this figure it's clear that, for cement blocks contain rice husk ash, compressive strength increases gradually from 55 to 530KN by increasing amount of additive from 1 to 3gm.

The increase in compressive strength may be due to the pozzolanic reaction between silica and the hydration of silica itself and calcium hydroxide. Concrete is known as a shatterable material, relatively strong under compression, however equally weak when subjected to tension. With increasing the substitution percentage of rice husk ash in cement matrices, reduction of strength with higher amounts of rice husk ash in concrete, this brittleness increases so the compressive strength decrease [26]. For cement-KOH treated rice husk ash samples, compressive strength decreases from 55 to 30KN by increasing amount of additives from 1gm to 3gm as shown in figure (2). Treatment of rice husk ash by KOH lead to increase in amount of alkalis present which act as an accelerator for crystallization of SiO_2 leading to reduction in pozzolanic activity of rice husk and decrease in compressive strength [27].

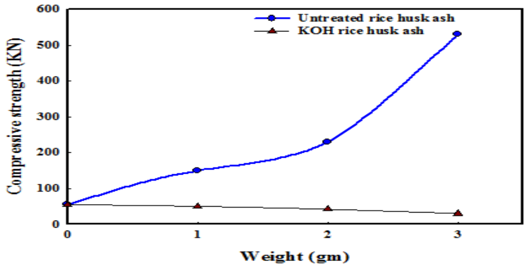

Figure (2): Effect of rice husk ash weight on compressive strength for cement samples.

3.1.1. Effect of temperature on compressive strength

For studying effect of high temperatures on compressive strength, the samples were exposed to different temperatures (50-100-150-200°C) and compressive strength measured at each degree for three times and average calculated. Its observed that, compressive strength decreases gradually as temperature increase. This may be due to that as the temperature of the block increased above the room temperature, the block absorbs water at a faster rate leading to cracks in block [28] as shown in figure (3).

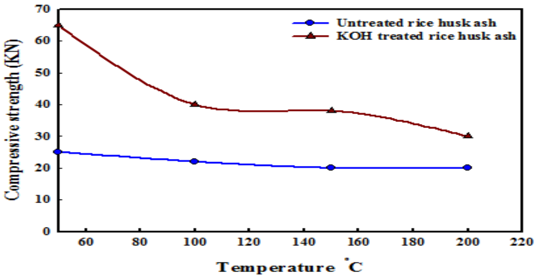

Figure (3): Effect of temperature on the compressive strength for cement samples contain 1gm of rice husk ash.

3.2. Fourier Transform Infrared Spectroscopic Analysis (FTIR)

IR spectrum of cement sample contain 1 gm of rice husk ash (untreated, treated) is shown in figure (4), where (0), (1) and (2) are the spectra of plain Portland cement, cement-untreated rice husk ash and cement-KOH treated rice husk ash respectively. For rice husk ash spectra, there is a change observed in band appeared at 3390 cm^{-1} and this is due to interaction between O-H group of $Ca(OH)_2$ of cement and that of rice husk ash. The change observed in the band at 2900 cm^{-1} which is due to C-H of alkyl is due to interaction between rice husk ash and cement components. The peak at ~1720 cm^{-1} due to the C=O stretching of p-coumaric acids of lignin and the acetyl groups of hemicellulose. Between 1100–950 cm^{-1} region, due to Si-O stretching, shifted to lower wave-numbers due to the decreasing polymerization [10].

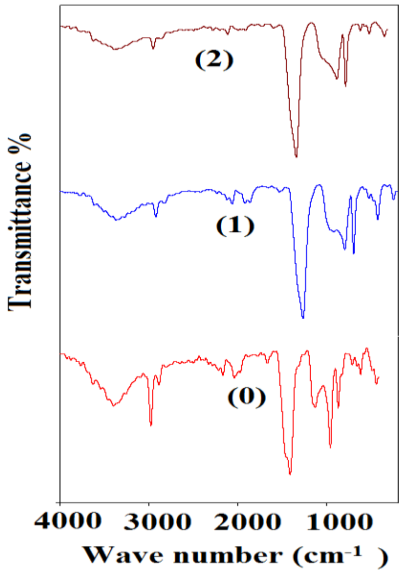

Figure (4): IR spectrum for cement-rice husk ash samples.

3.3. Thermogravimetric Analysis (TGA)

The thermal decomposition of cement-rice husk ash sample is shown in figure (5). It is observed that there are three peaks which can be named as stages in the decomposition. The first peak is observed as loss of absorbed water. Then second peak which is exothermic peak is followed by rapid weight loss indicates the decomposition of cellulose. The weight of rice husk ash continued to loss at the third peak that has observed as an ongoing decomposition of lignin and another organic constituent. For cement-untreated rice husk ash sample, in the first stage of thermogram the weight loss was about 10% at 300 ºC, and for KOH treated rice husk ash sample the weight loss was about 6.9% at 230 ºC. In the second stage which is the decomposition of the components of the sample, for untreated rice husk ash the weight loss was about 13% when temperature increase from 430 to 460 °C and for KOH treated rice husk ash the weight loss was 14% as temperature increase from 230 to 460 °C. In the final stage, for untreated rice husk ash sample the weight loss was about 25.5% as temperature increase, and for KOH treated rice husk ash the weight loss was 24.25%.

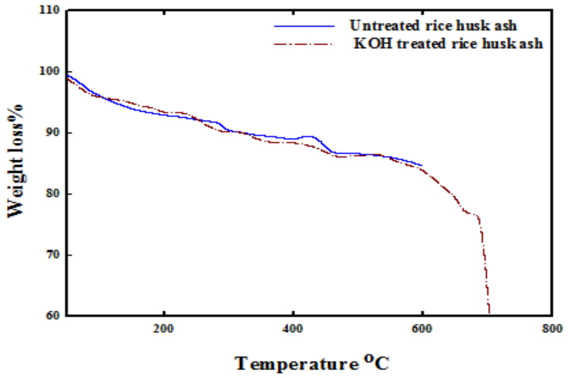

Figure (5): TGA for cement samples contain 1 gm of rice husk ash.

ı ıme (day)

3.4. Leaching behavior

3.4.1. Effect of contact time on the leaching process

The effect of contact time on the leaching behavior of solidified waste block using different types of leachants is very important for safe disposal of wastes. Therefore, the effect of contact time from 15minute to 30 days on the leaching behavior of solidified cemented block has been studied at room temperature and the data obtained are represented in figures below.

3.4.1.1. Effect of contact time on leaching behavior for Cobalt loaded on rice husk ash and incorporated into Portland cement

The effect of the contact time on the leaching behavior of Cobalt ion (Co^{+2} 50ppm) loaded onto untreated and KOH treated rice husk ash and incorporated into Portland cement, and using distilled water as leachant is shown in figure (6.a). Its observed that the leaching percent decreases from 0.38 to 0.09% for untreated rice husk ash and from 0.52 to 0.1% for KOH treated rice husk ash and reached to steady state after 2 days. While the leaching behavior using underground water as leachant, for untreated rice husk ash loaded by Cobalt the leaching percent decrease gradually from 0.08 to 0.028% as the contact time increase and reach steady state at 2 days as shown in figure (6.b). Additionally, sharp decrease from 0.14 to 0.009% through the first 30 minute with KOH treated rice husk ash loaded by Cobalt and then gradually decrease until reach steady state after 1 hour as shown in figure (6.b).

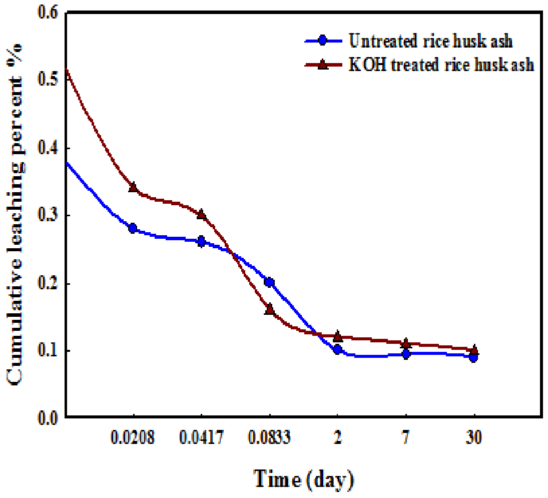

Figure (6.a): Effect of contact time on leaching behavior for samples contain Co^{+2} using distilled water as leachant [Co^{+2} conc.=50 ppm, leachant volume=200ml, sample dimensions=5*1 cm].

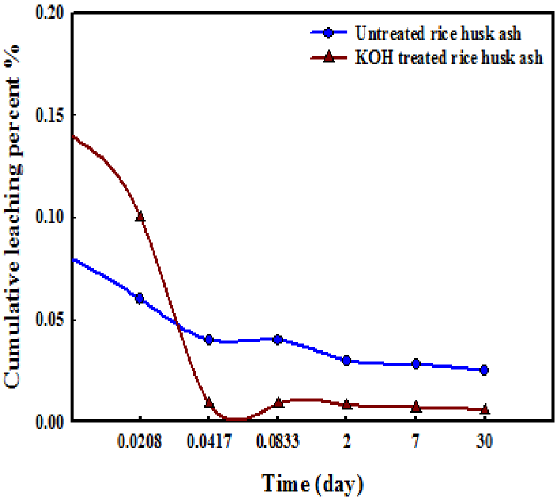

Figure (6.b): Effect of contact time on leaching behavior for samples contain Co^{+2} using underground water as leachant [Co^{+2} conc.=50 ppm, leachant volume=200ml, sample dimensions=5*1 cm].

Generally, the leaching percent in case of underground water as a leachant is higher than for distilled water and this may be due to the high salt content in underground water which leads to cracks in cement blocks leading to decrease in stabilization of cobalt in cement blocks and being leached.

3.4.1.2. Effect of contact time on leaching behavior for Strontium loaded on rice husk ash and incorporated into Portland cement

The effect of contact time changes on leaching behavior for Strontium ion (Sr^{+2} 50ppm) loaded on untreated and KOH treated rice husk ash and incorporated into Portland cement has been studied and the data obtained are represented in figures (7.a, 7.b). From the figures it's clear that for using distilled water as leachant, the leaching percent decrease gradually until reaching steady state after 7 days for both untreated and KOH treated rice husk ash samples. For using underground water as leachant, the cumulative leaching percent decreases with increasing contact time and reached to steady state after 7 days for untreated and KOH treated rice husk ash samples. Additionally, its observed that the leaching fraction is higher in case of KOH treated rice husk ash samples than untreated samples and this may be due to that Strontium is readily soluble into NaOH and KOH [29]. Some studies proved that the rice husk ash has a high ability to adsorb metals, so the Strontium can be well stabilized on the cement mortar [29, 30, 31].

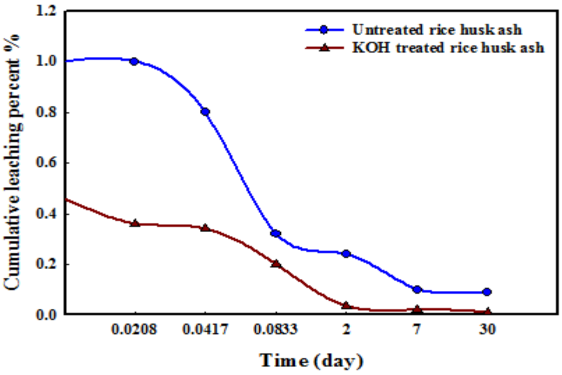

Figure (7.a): Effect of contact time on leaching behavior for samples contain Sr^{+2} using distilled water as leachant [Sr^{+2} conc.=50 ppm, leachant volume=200ml, sample dimensions=5*1 cm].

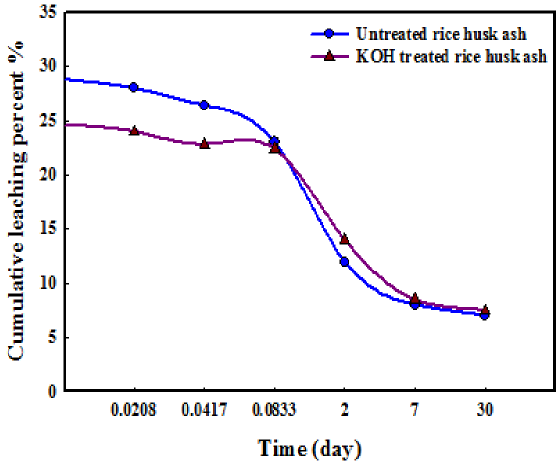

Figure (7.b): Effect of contact time on leaching behavior for samples contain Sr^{+2} using underground water as leachant [Sr^{+2} conc.=50 ppm, leachant volume=200ml, sample dimensions=5*1 cm].

At the starting of the leaching test (before seven days), the Sr^{+2} leaching rate decreased rapidly, but after this the rate begin to slow and tend to be consistent and gradually reached the steady state. Portion of the Sr^{+2} sticking to the surface of the solidified block contacting the leachant is dissolved at the beginning of the leaching tests. The Sr^{+2} present in the connected pore solution also enters the leachate by liquid–liquid diffusion. The solution in closed pores is in equilibrium with the solid phase. As the leaching period increases, portion of the Sr^{+2} encapsulated inside the cemented solidified body was gradually released to the outer surface of the cemented body by solid phase diffusion, and this can also enter the leaching solution. The cemented body continue the hydration during the leaching process, and so more hydration products are formed to fill the pores, which reduces the diffusion rate of Sr^{+2}. Therefore, the leaching rate of the cemented body tends to be high during the early stage and low during the later stages [32].

3.4.1.3. Effect of contact time on leaching behavior for Cesium loaded on rice husk ash and incorporated into Portland cement

The effect of contact time on leaching behavior for Cesium ion (Cs^{+} 50 ppm) loaded on rice husk ash and incorporated into cement block has been studied and the data obtained are shown in figures (8.a, 8.b). From the figures it's clear that for using distilled water as leachant, by increasing contact time the leaching percent increase gradually until reaching steady state after 2 days for both untreated and KOH treated rice husk ash. Meanwhile for using underground water as leachant with increasing the contact time, the cumulative leaching percent increases and reached to steady state after one month for both untreated and KOH treated rice husk ash.

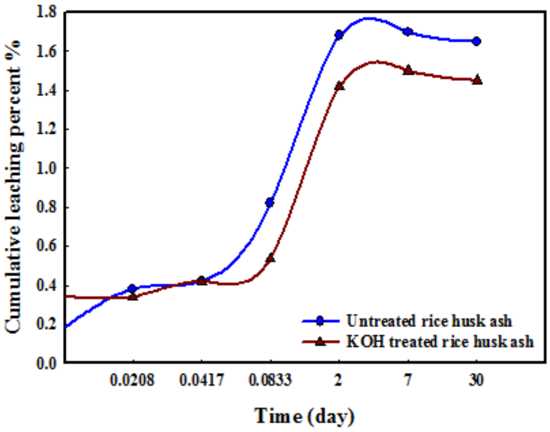

Figure (8.a): Effect of contact time on leaching behavior for samples contain Cs^{+} using distilled water as leachant [Cs^{+2} conc.=50 ppm, leachant volume=200ml, sample dimensions=5*1 cm].

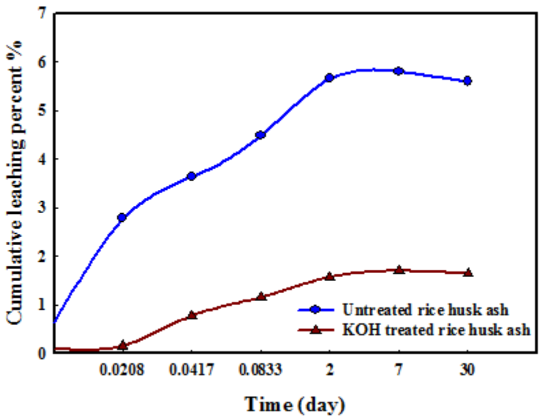

Figure (8.b): Effect of contact time on leaching behavior for samples contain Cs^+ using distilled water as leachant [Cs^{+2} conc.=50 ppm, leachant volume=200ml, sample dimensions=5*1 cm].

Because of the high mobility of Cesium, as soluble species, it is badly adsorbed in the alkaline media of cement and so it releases more efficiently than Cobalt which produces insoluble hydroxides in the alkaline cement medium [31]. It's also observed from the data obtained that Cesium has highest values of cumulative leach fraction than Strontium radionuclide [30]. Cesium was released more than Cobalt, but these rates of release are relatively low. This result confirms the chemical stability of solidified specimens containing radioactive waste during various leaching tests, so cement can be considered as an acceptable inexpensive material to stabilize radioactive waste [31].

3.4.2. *Effect of concentration on leaching process*

The initial concentration plays important role on the migration of Cobalt, Strontium and Cesium from solidified waste blocks. Also the type of the contaminated natural materials (untreated and treated) affected on the transportation process of metal ions from waste block.

3.4.2.1. Effect of concentration on leaching behavior for Cobalt loaded on rice husk ash and incorporated into Portland cement

The effect of concentration on the leaching behavior for Cobalt loaded on rice husk ash and fixed into Portland cement has been studied at room temperature and at constant contact time and the data obtained is represented in figures (9.a, 9.b). From the data obtained its observed that as the initial concentration of Cobalt increased from 50 to 200 ppm the leaching percent increases gradually for untreated and KOH treated rice husk ash from 0.01 to 0.09% and from 0.02 to 0.099% respectively as using distilled water as leachant as shown in figure (9.a).

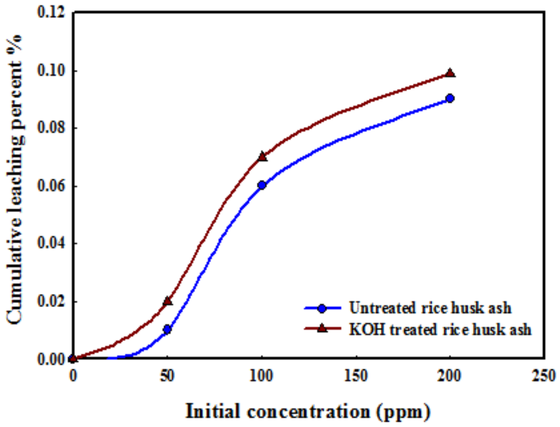

Figure (9.a): Effect of metal ion concentration on leaching behavior for samples contain Co^{+2} using distilled water as leachant [contact time=1month, leachant volume=200ml, sample dimensions=5*1 cm].

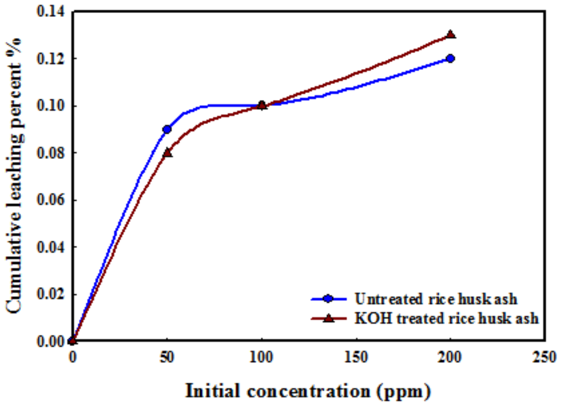

Figure (9.b): Effect of metal ion concentration on leaching behavior for samples contain Co^{+2} using underground water as leachant [contact time=1month, leachant volume=200ml, sample dimensions=5*1 cm].

Increasing the waste concentration will lead to the formation of porous materials and subsequently increase the permeability [2]. Many metal ions and salts make a chemical linkage with cement components, or they exist separated in the state of singular crystals in concrete. When the solidified waste specimens come in contact with water, the migration of soluble materials from the waste to the surrounding water is caused by chemical reaction with chemical components of water or dissolution. In this study, the metal ions chosen for the leaching test are intended to represent the desorption (leaching) behavior of some of the typical radionuclides observed in low-level solid waste forms [3]. Its observed that the leaching percents from cemented block are in the following order: $Cs^+ > Sr^{+2} > Co^{+2}$ and this may be due to the high solubility and low sorption potential of Cs^+ than the other two ions. Metal ions leaching from the cemented matrices occurs in the following steps:

surface wash-off, diffusion, and dissolution. The initial rapid leaching of elements attached to the solid waste surface occurred due to surface wash-off. Following this a mass transfer occurred due to diffusion from the pore space of the solidified waste to the solution [14].

Figure (9.b) shows that, in case of using underground water as leachant, by increasing initial concentration of Cobalt ion, the cumulative leaching percent increases from 0.09 to 0.12% and from 0.08 to 0.13% for untreated and KOH treated rice husk ash.

From both figure 9.a, 9.b it was observed that The leaching percent for using distilled water as leachant is lower than that in case of using underground water as leachant and this may be due to that underground water contain salts that penetrate the cement block and cause pores allowing cobalt to leach out of the block [2].

3.4.2.2. Effect of concentration on leaching behavior of Sr^{+2} loaded on rice husk ash and incorporated into Portland cement

The effect of concentration on leaching behavior of Strontium ion loaded on rice husk ash has been studied at room temperature and the data obtained are represented in figures (10.a, 10.b). From these figures it's clear that the cumulative leaching percent increases with increasing metal ion concentration from 50 to 200 ppm for both leachant (distilled water and underground water). Figure (10.a) shows that, in case of using distilled water as leachant, the cumulative leach percent for solidified Sr^{+2} loaded on untreated rice husk ash increased from 0.02 to 0.13% by increasing the concentration of Sr^{+2} from 50 to 200 ppm, while for KOH treated rice husk ash it increased from 0.01 to 0.14% as the initial concentration of Sr^{+2} increase from 50 to 200 ppm.

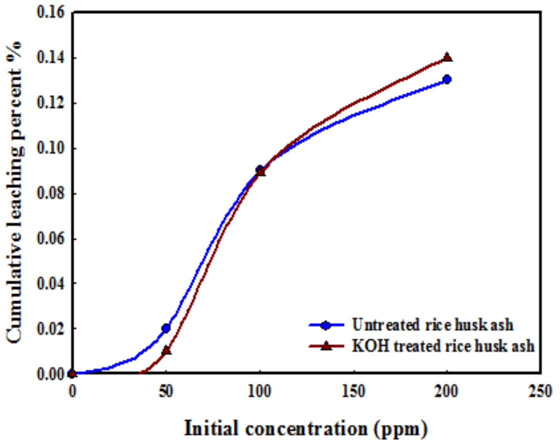

Figure (10.a): Effect of metal ion concentration on leaching behavior for samples contain Sr^{+2} using distilled water as leachant [contact time=1month, leachant volume=200ml, sample dimensions=5*1 cm].

Figure (10.b), in case of using underground water as leachant, the cumulative leach percent for solidified Sr^{+2} loaded on untreated rice husk ash increased from 0.04 to 0.17% by increasing Sr^{+2} concentration from 50 to 200 ppm, while for KOH treated rice husk ash it increased from 0.045 to 0.2% with increasing Sr^{+2} concentration from 50 to 200 ppm.

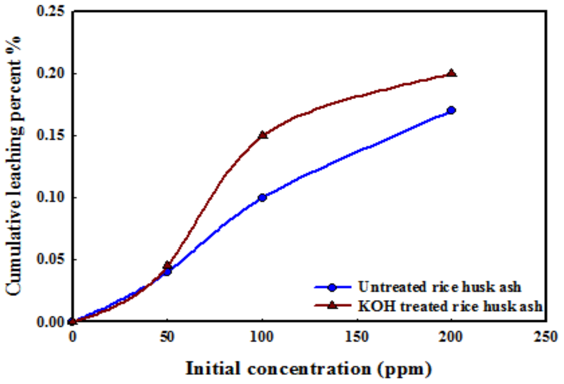

Figure (10.b): Effect of metal ion concentration on leaching behavior for samples contain Sr^{+2} using underground water as leachant [contact time=1month, leachant volume=200ml, sample dimensions=5*1 cm].

3.2.2.3. Effect of concentration on leaching behavior of Cs^{+} loaded on rice husk ash and incorporated into Portland cement

Figure (11.a) show the effect of concentration of cesium ion on leaching behavior of Cs^{+} while using distilled water as leachant. From the figure it's clear that, as the concentration of Cs^{+} increase from 50 to 200ppm, the cumulative leaching percent of Cs^{+} increases gradually for both untreated and KOH treated rice husk ash from 0.2 to 0.33% and from 0.1 to 0.35% respectively.

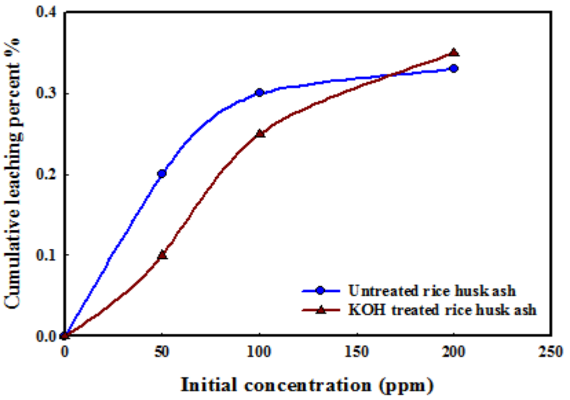

Figure (11.a): Effect of metal ion concentration on leaching behavior for samples contain Cs^{+} using distilled water as leachant [contact time=1month, leachant volume=200ml, sample dimensions=5*1 cm].

While at the same concentration (50 to 200 ppm) by using underground water as leachant, the cumulative leaching percent of Cesium increase from 0.13 to 0.39% and from 0.12 to 0.4% for untreated and KOH treated samples respectively as shown in figure (11.b). It was observed that, the cumulative leach percent has the following order: $Cs^+ > Sr^{+2} > Co^{+2}$.

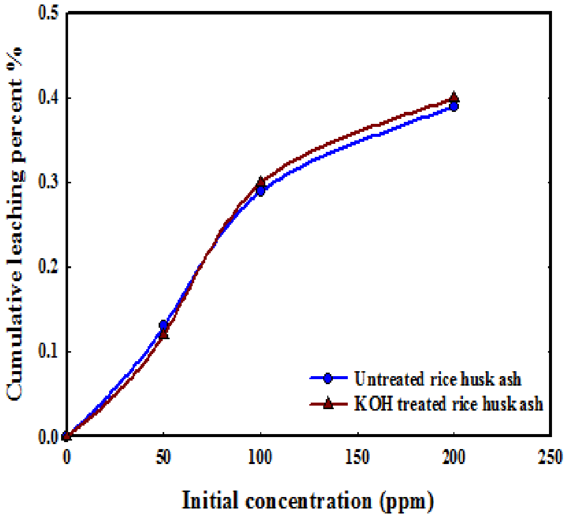

Figure (11.b): Effect of metal ion concentration on leaching behavior for samples contain Cs^+ using underground water as leachant [contact time=1month, leachant volume=200ml, sample dimensions=5*1 cm].

4. Conclusion

The conclusion of this study can be summarized as follow:

Rice husk ash in form of untreated or KOH treated species can be used to improve resistance of Portland cement against leaching of radioactive wastes. Untreated rice husk ash can be used effectively in improving mechanical properties of Portland cement, but for KOH treated rice husk ash the increase in weight added of rice husk lead to reduction in compressive strength of solidified block. It was observed that, the cumulative leach percent has the following order: $Cs^+ > Sr^{+2} > Co^{+2}$.

As contact time increase the leaching is high first then decrease with time until reach steady state. As concentration of the metal ions studied increase the cumulative leaching percent increases gradually. The leaching behavior in case of using underground water as leachant is higher than in case of using distilled water.

5. Conflicts of interest

"There are no conflicts to declare".

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