5. SUMMARY AND CONCLUSION

5.1. Summary:

This thesis is concerned with some fundamental studies related to the removal of radioisotopes which arise from the different applications of nuclear industry. This thesis is also concerned with solidification of liquid radioactive wastes in ordinary portland cement (OPC) to obtain safety disposal for this kind of radioactive liquid waste.

The main aim of this work is: **1)** to remove certain radioactive ions mainly cesium-137, cobalt-60 and europium-(152+154) from their liquid solutions using certain industrial solid wastes; homra, fly ash, silica fume, ceramic and window glass at different conditions. **2)** to study the different parameters affecting the removal process. **3)** to study the solidification of the studied radioactive ions in different matrices: plain ordinary portland cement (OPC) and OPC mixed with homra, fly ash, silica fume, ceramic and window glass. **4)** to study the physical, mechanical and chemical properties of the solidified waste products.

The characterization of industrial solid wastes were performed using X-ray diffraction, X-ray flourescence and IR analysis.

The thesis was classified into four chapters namely; **1)** Introduction, **2)** Literature review, **3)** Materials and methods, **4)** Results and discussion.

The First Chapter: Introduction: It includes some aspects on the sources of radioactive waste, classification of radioactive wastes, removal and conditioning of low level radioactive liquid waste, as well as the industrial solid wastes that used as sorbents.

The Second Chapter: Literature review: It includes a collection of literatures that were published in recent years in this respect.

The Third Chapter: Experimental: It includes the chemicals used, the preparation of the simulated radioactive liquid waste, equipment and methods of investigations applied.

The Fourth Chapter: Results and Discussion: This chapter was classified into two parts.

First: Treatment of low level radioactive liquid waste using industrial solid wastes.

The detailed study in this part includes:

1. Evaluation of the use of the industrial solid wastes; mainly: homra, fly ash, silica fume, ceramic and window glass as sorbents to remove the radioisotopes, ^{137}Cs , ^{60}Co, and $^{152+154}Eu$, from the low level liquid wastes.

2. Measuring of the time required for complete sorption which was found about 40 min at the ambient room temperature ($25\pm1^{\circ}C$) with all the investigated solids.

3. Homra showed that the greatest uptake % values in comparison to the other solids due to its greatest high surface area.

4. The sorption of all the radioactive cations ^{137}Cs, ^{60}Co, and $^{152+154}Eu$ was found to increase in alkaline medium, while in acidic medium the sorption was decreased.

5. Eu^{3+} gives the highest uptake % with all studied industrial solid wastes followed by Co^{2+} and Cs^{+} , which is in related to their ionic size according to the following arrangement $Eu^{3+} < Co^{2+} < Cs^{+}$.

6. The sorption process of Cs^{+} and Co^{2+} was affected by the particle size of sorbents, where the uptake % increased by the increase in the particle size . This was not found with Eu^{3+} and can be related to its smallest ionic size that can fill any kinds of pores .

7. Sorption process of Cs^{+} and Co^{2+} was also affected by the weight of the investigated solid wastes added to the low level liquid waste, where the uptake % increased with increasing the weight of the added solid waste. This was not found with Eu^{3+} and can be related to its smallest ionic size .

8. The study showed that, uptake % values were in the ranges 93.1-99.1% for Eu^{3+}, 85.9-94.2% for Co^{2+} and 56.8-93.1% for Cs^{+} for all the industrial solid wastes studied.

From the results obtained it can be concluded that, the removal of the radioisotopes, ^{137}Cs, ^{60}Co, and $^{152+154}Eu$, from the liquid wasteusing the industrial solid wastes under investigation as sorbents could be performed successfully by this technique.

Second: Solidification of radioactive liquid waste adsorbed on the solid wastes and mixed with ordinary portland cement (OPC).

In this part the investigated industrial solid wastes and mixed with (OPC) to evaluate the physical and chemical properties for the solidified waste products to save disposal to protect man and environment.

From the different parameters studied on the solidified waste forms it can be concluded that,

1. The effect of curing time on the mechanical strength of the cement pastes, the mechanical strength increased with increasing the curing time, and the maximum mechanical strength was achieved after curing for 28 days.

2. The setting times (initial and final) of the cement pastes mixed with 5% for each homra, fly ash, silica fume, ceramic and window glass gives more calcium silicate hydrate (CSH) formation which decreased both the initial and final setting times so, the addition of such materials improved the properties of cement pastes used.

3. The bleeding capacity and bleeding rate of the mixed cement pastes mixed with 5% of homra, fly ash, silica fume, ceramic and window glass to OPC decreased both the bleeding capacity and bleeding rate as they are good fillers.

4. The effect of water immersion for one and three months in different leachant; sea, tap and distilled water on the mechanical strength of the mixed hard cement, the solidified waste forms immersed in sea water had mechanical strength values higher than those immersed in tap water and distilled water. This phenomenon was attributed to that, the immersing medium (sea water) acts as an accelarator, where the sulfate ions activate the hydration of granulated slag. As a result of this activation, both calcium sulphoaluminate and calcium silicate hydrates are formed filling up the available pore volume and leades to increasing in mechanical strength.

5. The mechanical strength of the cement hard, as a function of the solid wastes weight added to the OPC, The mechanical strength increased by the addition of the industrial solid wastes due to they produce additional amount of calcium silicate and aluminosilicate hydrates. The maximum mechanical strength was achieved after addition of 15% homra, ceramic and silica fume, 5% of fly ash and 20% window glass. Any additions after these percentages decrease the mechanical strength which may be attributed to the decrease in clinker content.

6. The long-term leachability evaluation for the cement hard mixed with 5% of solid waste give lowers cumulative fractions. This can be attributed to solid wastes added (pozzolanic materials) contain silica and alumina which react with calcium hydroxide (lime) produced during the hydration of cement to form calcium silicates which prevent the movement and diffusion of the radionuclides from the immobilized waste. For all investigated radioactive ions, the leaching rate was found to decrease in the sequence $Cs^{+} > Co^{2+} > Eu^{3+}$.

7. The rapid leaching test for the hard cement mixed with 5% solid wastes investigated decreased leaching rates. Cs^{+} has the maximum values of leaching rates

The cumulative fraction of the solidified waste forms are arrangement according to the following sequences:

OPC > (OPC+S.F) > (OPC+F.A) > (OPC+C) > (OPC+H) > (OPC+W.G).

5.2. Conclusion:

From the proceeding studies, the following could be concluded:

1- The industrial waste materials as homra, fly ash, silica fume, ceramic and window glass can be used as sorbents to remove the radioactive nuclides as ^{137}Cs, ^{60}Co, and $^{152+154}Eu$ from their solutions to reduce the volume of the respective radioactive liquid waste.

2- Chemical sorption is a simple technique for the removal of the radioisotopes ^{137}Cs, ^{60}Co, and $^{152+154}Eu$, and the reactions of these ions with the industrial materials: homra, fly ash, silica fume, ceramic and window glass is fast where they attain equilibrium within 40 min.

3- These industrial materials also improve largely the properties of the familiar materials for solidification, ordinary portland cement, so they can be used for a safe disposal of such radioactive nuclides.

4- The highest uptake of the radioactive ions reached in the alkali medium.

5- Homra shows a great affinity towards the radioactive ions rather than the other solids investigated (fly ash, silica fume, ceramic and window glass).

6- Silica fume show a superior performance of the mechanical strength when added to the ordinary portland cement.

7- Window glass has a minimum leached rate than the other materials (homra, fly ash, silica fume and ceramic).

8- Europium complex appears to be stronger as the percent leached is smaller than the other metal complexes experimented (^{137}Cs and ^{60}Co).

9- From this study it is satisfactorily recommended to use these industrial solid wastes in the removal and solidification of the radioisotopes as they are good sorbents and fillers to the ordinary portland cement.