ANNEXURE IX

PROJECT COMPLETION REPORT

UNIVERSITY GRANTS COMMISSION BAHADUR SHAH ZAFAR MARG NEW DELHI– 110 002

PROFORMA FOR SUBMISSION OF INFORMATION AT THE TIME OF SENDING THE FINAL REPORT OF THE WORK DONE ON THE PROJECT

1. **Title of the Project**

   IONIC SUBSTITUTION IN NANODIMENSIONAL HYDROXYAPATITE FOR BONE TISSUE ENGINEERING APPLICATIONS

2. **NAME AND ADDRESS OF THE PRINCIPAL INVESTIGATOR**

   Prof. Seema Kapoor
   Dr. S.S.Bhatnagar University Institute of Chemical Engineering & Technology
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3. **NAME AND ADDRESS OF THE INSTITUTION**

   Dr. S.S.Bhatnagar University Institute of Chemical Engineering & Technology
   Panjab University, Chandigarh-160014

4. **UGC APPROVAL LETTER NO. AND DATE**

   File No. -43-155/2014(SR) dated 01 July 2015

5. **DATE OF IMPLEMENTATION**: 01 July 2015
6. **TENURE OF THE PROJECT**: 01 July 2015 to 30 June 2018
7. **TOTAL GRANT ALLOCATED**: Rs. 14,06,000/-
8. **TOTAL GRANT RECEIVED**: Rs. 13,29,000/-
9. **FINAL EXPENDITURE**: Rs. 12,69,577/- (exclusive of pending liabilities of Rs. 57,600/-)
10. **TITLE OF THE PROJECT**: IONIC SUBSTITUTION IN NANODIMENSIONAL HYDROXYAPATITE (HA) FOR BONE TISSUE ENGINEERING APPLICATIONS
11. **OBJECTIVES OF THE PROJECT**
    - Synthesis of nanodimensional HA and ionic substituted HAs.
    - Calcination of synthesized nanopowders for phase transformations of HA to β-tricalcium phosphate and α-tricalcium phosphate.

- Study of physicochemical, structural and thermal behavior of synthesized and calcined nanopowders.
- Study of the effect of ionic substitution on physicochemical and thermal behavior of iHAs.
- Study of in-vitro behavior of HAs and iHAs.
- Data analysis and interpretation of results.

12. WHETHER OBJECTIVES WERE ACHIEVED

The project has been completed with all the objectives being successfully achieved.

Nanodimensional hydroxyapatite and ionic substituted hydroxyapatite nanopowders were successfully synthesized by water based sol-gel technique. The ionic substitution in hydroxyapatite was confirmed from XRF spectra, however the content of substitution in as-synthesized nanopowders varied from their initial contents in the preparatory solutions.

On calcination of these nanopowders, the morphology changed either to rod-like or spherical. Also the particle size increased on calcination. The BET surface area of calcined nanopowders was higher than as-synthesized nanopowders, which might be due to sintering effect within the powder particles.

As indicated from XRD patterns, as-synthesized nanopowders possessed pure phase of HA, which matched well with JCPDS card no. 09-432. On calcination of these nanopowders, the hydroxyapatite phase partially transformed to β-TCP phase, resulting in biphasic mixture of HA and β-TCP.

As-synthesized nanopowders were amorphous in nature. The crystallinity increased with calcination temperature. The mean crystallite sizes of as-synthesized nanopowders were in the nano range (20-29 nm). The lattice parameters 'a' and 'c' of nanopowder crystallites varied on substitution of ions in hydroxyapatite and also on calcination. These values were within the range as reported for stoichiometric hydroxyapatite. The c/a ratio for as-synthesized and calcined nanopowders was around 0.73, indicating the crystallographic stability of nanopowders.

The FTIR spectrum of as-synthesized and calcined nanopowders confirmed the characteristic peaks of pure hydroxyapatite and ionic substituted hydroxyapatite.

In-vitro analysis of as-synthesized and calcined nanopowders on immersion in simulated body fluid (SBF) for 30 days showed almost similar trend of alternate decrease and increase of pH in SBF confirming the bioactive behavior of nanopowders. The growth of globules of apatite like phase on the surface nanopowders from TEM micrographs further confirmed the deposition of apatite layer on their surface. The same is expected under in-vivo conditions and is likely to help in promoting bone growth.

The present study also exploited the ion exchange approach in hydroxyapatite for removal of lead (Pb^{2+}) from waste water. The work involved using nanodimensional hydroxyapatite as adsorbent for heavy metal ion and investigating systematically the removal characteristics of hydroxyapatite for Pb^{2+}. The uptake process by hydroxyapatite obeyed the kinetic equation describing adsorption. This, together with the correlation found between lead uptake and the amount of calcium release into the solution, confirmed that ion exchange was the basic mechanism of uptake. The kinetic experimental data were properly correlated with the second order kinetic model.

13. ACHIEVEMENTS FROM THE PROJECT

The project resulted in 2 journal publications and one paper presentation at an International conference titled '17th European Conference on Composite Materials, ECCM-17' held at Munich, Germany from June 26-30, 2016.

14. SUMMARY OF THE FINDINGS

The present project was successful in exploring the role of ion substitution in hydroxyapatite by adding ions individually or in combination on lattice parameters, crystallinity, particle size and other physico-chemical, thermal and in-vitro properties of hydroxyapatite.

It was found that this study of ionic substitution in hydroxyapatite was relevant and useful for better understanding of the biomineralization process, control of properties, increase in bioactivity and delivery of ions able to treat bone diseases.

The incorporation of ions into hydroxyapatite has shown to be beneficial in improving osteoblast response in terms of adhesion, differentiation, proliferation and mineralization processes and also in stimulating bone tissue formation compared to pure hydroxyapatite. Thus the present work is of great significance for dental and orthopedic applications.

As the Ca^{2+} ions in the hydroxyapatite crystal could easily be replaced by divalent metal cations, so this project also exploited the use of nanodimensional hydroxyapatite as adsorbent for heavy metal immobilization (metal ions like lead, Pb^{2+}) as well as remediation of ground water in the contaminated soils.

15. CONTRIBUTION TO THE SOCIETY

The outcome of this project is quite relevant to our society.

Being similar in composition to natural bone, the ionic substituted hydroxyapatite will be a material of choice for repairing damaged bone. Scaffolds made from such materials can be used for bone regeneration and drug delivery systems. Also these materials can be used for coatings on metallic implants made up of stainless steel and Ti6Al4V alloys. Thus with bone regeneration potential and being cost effective, ionic substituted hydroxyapatite will be useful in clinical applications like bone fillers and bone grafts.

16. WHETHER ANY PH.D. ENROLLED/PRODUCED OUT OF THE PROJECT: NA

17. NUMBER OF PUBLICATIONS OUT OF THE PROJECT: 2

(PRINCIPAL INVESTIGATOR) **(REGISTRAR/PRINCIPAL)**

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