Metal Conservation

Dr. V. Jeyaraj

METAL CONSERVATION

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FOREWORD

The Chemical Conservation and Research Laboratory of the Government Museum, Chennai is the pioneering Chemical Conservation Laboratory attached to the museums in this country. It was established to conserve the bronze icons received through the Indian Treasure-trove Act. Slowly this laboratory was involved in the conservation of wall paintings in Tamil Nadu. Dr. S. Paramasivan was the first Curator of this Laboratory. His yeoman service in this field is known to the whole world through his publications in this field. After Dr. S. Paramasivan, many stalwarts like Mr. N. Harinarayana worked in this Laboratory and brought it to the forefront. It was during the tenure of Dr. V. Jeyaraj, the Laboratory was recognized as a research institution by the University of Madras to conduct research leading to the award of Ph. D. Degree. At present four researchers are working under him for the award of Ph.D. in chemical conservation of museum antiquities and related materials. The publications of this Laboratory are well known in the field of conservation. Besides conservation work, this laboratory extends conservation consultancy services to those who are in need of it. This is the first Laboratory in Asia, which offered training in conservation for the first time. At present various conservation courses are being organized regularly in this Laboratory. The latest being the weeklong Capsule Courses on Conservation of Cultural Heritage at Chennai, Tiruchirappalli, Salem and Madurai and the last course was successfully conducted during November 2002 in which 32 participants from departments like Museums, Archaeology, Hindu

Religious and Charitable Endowments, Southern Railway and Police participated. The main thrust of the course was to provide training to the officials in charge of cultural institutions to chemically clean the structural stone monuments like temples instead of the deleterious sand blasting. These programmes were well publicized in the media.

One of the activities of the Chemical Conservation and Research Laboratory of the museum is conducting seminars and workshops on conservation. One International seminar on Conservation of Stone Objects was conducted in December 2001. It is proposed to conduct an International Workshop on Metal Conservation at Lucknow, Hyderabad, Chennai and Thanjavur by National Research Laboratory for Conservation, Lucknow. The workshop at Chennai has been arranged on 11th December 2002 under the co-ordination of Thiru. K. Lakshiminarayanan, Assistant Director of Museums and with the help of Curators Messers R. Balasubramaniam, Mr. P. Jawahar, Mr. J.R. Ashokan, Mr. K. Sekar, Mr. M. Mohan and Ms. R. Shanthi, Ms. M. N. Pushpa and Ms. A. Prema Dheebarani and staff of the Chemical Conservation and Research Laboratory, Messers J. D. Jagannathan, M. Raja Balachandra Murugan and S. Sampath.

In order to publicise the work done in the Laboratory and also to educate those interested in conservation of metal antiquities, Dr. V. Jeyaraj has brought out a book on Metal Conservation with the help of IASC Chennai Regional Chapter. This will be useful to those who are engaged in the profession of metal conservation and those who are in charge of metal antiquities. I am sure he will write many more books in this field enabling those in-charge of the cultural heritage and those interested in preserving the cultural heritage for posterity.

Chennai-600 008,
(R. KANNAN)
28-11-2002.

(Dr. R. Kannan, Ph.D., I.A.S.)

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Introduction

Metals as materials have more strength and flexibility of manipulation than stone or clay or wooden objects; but when it comes to chemical stability, they (except gold and silver) fall far short of the latter. They are susceptible to many factors, which bring about their deterioration, resulting in the formation of deleterious compounds conducive for further deterioration and the ultimate transformation into forms (ores/minerals) in which form(s) they occur in nature. Corrosion is the menace that the conservator faces with metallic antiquities.

The principle behind this is that when objects are buried for a long time under certain conditions that are reasonably constant, they tend to attain a state of equilibrium with their surroundings. This will constitute the first stage in metallic corrosion. Soon after excavation these materials are once again exposed to yet another entirely new environment upsetting the earliest equilibrium in which they had been conditioned; and owing to such series of changes, most metallic objects are profoundly affected. Metallic objects buried in salty ground are exposed not only to moisture but also to the action of corrosive salts dissolved in the ground water. In short, excavated objects exposed to a new environment may cause a new type of corrosion to break out afresh as they once again tend to adapt themselves to the new conditions. It is relevant to trace back our traditional method of protection from thieves by burying bronze icons in a pit filled with river sand, lime etc. after covering them with cloth objects, which are displayed/stored also tend to be corroded by the pollutants in the atmosphere. Therefore, there is a need for conserving metal objects by suitable means to posterity.

Factors Affecting Metal Objects

The deteriorating factors affecting metallic antiquities are:(1) Humidity/Temperature, (2) Air/ Contaminated air (with pollutants) and (3) Lack of maintenance.

(1) Humidity/Temperature

Humidity is the measure of moisture content in air/soil. Humidity brings about deleterious effects on metallic antiquities. Under excessive wet conditions corrosion on metals is encouraged. In damp and hot conditions bacterial and fungal growth further facilitate corrosion.

In India, especially in Tamil Nadu, the climatic condition is unfavourable for the upkeep of metal antiquities. Generally, the relative humidity in Chennai is very high, i.e., above 90% during July to January. The humidity is very low down to 27% during the month of June. During May it is comparatively low in the range between 30% to 40%. There is always a difference in the relative humidity and temperature inside and outside the galleries, which are not favourable for the long term preservation of antiquities. Relative humidity between 45%-60% and temperature between 20-25° C is ideal for metal antiquities under which condition the deterioration will be minimal. If air-contioned, it should be round the clock.

(2) Air/Pollutants

Oxygen, oxides of sulphur, carbon and nitrogen, hydrogen sulphide, chloride spray, etc., present in the air adversely affect the metal objects forming oxides, carbonates, sulphates, sulphides, nitrides and other complex corrosion products. The chloride salt spray present in the atmosphere along sea-shores adversely affect metallic antiquities forming the corresponding chlorides, which are deleterious to the metallic objects.

(3) Lack of Maintenance

Prolonged exposure to un-optimised temperature, humidity, etc., mishandling, vandalism, neglect, improper package and direction during transit, etc., also affect metallic antiquities to a great extent.

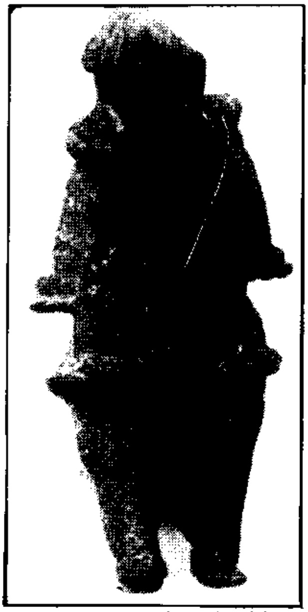
Bronze Antiquities

History of Bronze Technology

Bronze technology seems to have preceded iron in human civilization and had emerged in the Near East as early as 3000 B.C. There are historical records of the prevalence of bronze casting technology in India even before 2500 B.C. This is evidenced from the excavated bronze image of the dancing girl from Mohenjodaro, which is currently preserved in the National

Museum, New Delhi and the man-like figure found at the confluence of Ganges and Jamuna in North India, which has been dated to be about 1000 B.C.

Bronze technology in Tamil Nadu dates back to the 7th century B.C. evidenced from the bronze objects obtained from excavations at Adichanallur, Tirunelveli District, Tamil Nadu; these objects are today preserved in the Government Museum, Chennai. Recent excavations by the Department of Epigraphy of Tamil University, Thanjavur at Kodumanal, Erode district, Tamil Nadu, have brought to light a semi-precious stone-studded tiger bronze image belonging to circa 2000 B.C. Even though the bronze icon-making was in vogue during the Pallava period (close of 3rd to 9th century A.D.), the Pallavas have left too few of their icons to enable one to evaluate the full potential of the technological achievements prevalent in those periods. In spite of the existence of the bronze technology of the Pandhyas (2nd century B.C. to 17th century A.D.) the remains of bronze icons of that period are not many. During the reign of the Cholas (9th to 13th century A.D.), high quality bronze icons have been manufactured. Later, Vijayanagar kings encouraged the art of bronze icon-making in the 15th and 16th centuries A.D.



Bronze Mother Goddess, Adichanallur.

The bronze icons in the Government Museum, Chennai, acquired through the Treasure-trove Act of India, 1878 are mainly from Thanjavur, Trichirappalli and Pudukkottai districts of Tamil Nadu. Scientific examinations of these objects reveal the traditional casting was the technique in vogue. Bronze icon-casting technology by the traditional method is practiced even to this date at Swamimalai in Thanjavur and also in few other places in Tamil Nadu.

Generally bronze is an alloy of copper (75-80%) and tin (25-20%). Ancient bronze icons are generally considered to be made out of *panchaloha* connoting a five-metal alloy usually a composite alloy of metals-copper, tin, lead, silver and gold in varying proportion. But analysis of South Indian bronzes reveals that they invariably consist of copper, tin, lead, zinc and iron. Trace quantities of arsenic, antimony, bismuth are also detected in a few of them. It is believed that artisans used to add gold only to the face of the icon. Few grams in a 25 kilogram bronze icon is nothing. It will be only a trace quantity ie. less than 0.1%.

Methods of Bronze-casting

Basically the two popular methods of bronze casting practiced in India are:

1. Solid casting (*cire-perdue* meaning lost wax process) and
2. Hollow casting.

1. **Solid Casting**

The solid casting process is otherwise called *cire-perdue*, a French term meaning lost wax. The basic principle of the solid casting is that the image is first fashioned out of wax, then over it are la id in succession sufficiently thick, uniform layers of fine-grained clay (*'puthumann'*) followed by coarse sand with clay. The mould thus prepared is allowed to dry under shade, and then heated to about 80°C to let out the molten wax through openings provided in the clay layer. Finally molten bronze melt is poured into the hollow space thus created in the clay mould kept buried in the soil, taking care to fill every crevice and corner in the mould cast. The mould is allowed to cool and the clay layer is broken to bring out the cast bronze icon. This is then given the finishing touches by the artisan with chisel and

Solid Cast Bronze Icon with its Mould

hammer to bring out the finer details of the image. The icon is then given a final polish with fine sea-shore sand. By this method, it is possible to cast only one icon at a time. The laborious mould preparations should be repeated for every individual casting of the icon. The famed bronze master-pieces from Tamil Nadu are solid cast pieces. Government Museum, Chennai has a 10th Century A.D. bronze Nataraja along with the partial mould.

2. Hollow Casting

Since this type of casting of icons has an inner core of clay, it is called hollow casting. They will be comparatively light in weight. In this process, a slightly smaller sized image is made out of clay. Thread like wax is extruded on to the clay mould and wrapped around it. The wrapped wax is flattened out evenly to the contours of the image.

Finally the clay model is covered uniformly and completely with a thin layer of wax. Then the intricate details are worked out on the final wax layer. After the wax figure is fashioned to the required form and size, fine clay is applied over it. During the working of the clay mould, holes and inter connections (runners) are suitably provided to facilitate easy flow of the molten alloy in the hollow space around the inner clay core and the escape of hot gases during the pour process. The mould is cooled, and broken up carefully to reveal the image. To get the artistic details required for the image, finishing touches like chiseling, filing, polishing, etc., are effected by the artisans. By this method also only one piece can be made from a mould. Buddhist images are examples to this. Some times instead the clay model, iron core is also found in Chola period bronze lamps.


Hollow Cast Bronze

The technique of making a large sized bronze statue is to cast the image in pieces and assemble the separately cast fragments together by welding in the final stage. Several books on ancient technology on metallurgy, detail this art. Work on the 10 foot bronze statue of Dupleix of the 18th century A.D. at Pondicherry, is a classical example of the piece-mould hollow casting. Government Museum, Chennai has a more than life size bronze statue of Captain Neil, which is also another example for this.

Coins

Coins are one of the cultural and commercial remnants of the past through which our ancient history can be reconstructed. The coins used by our forefathers were buried for so many reasons and are now exposed through exploration, chance discoveries or excavations. Such coins are preserved in museums and similar public institutions for posterity. Coins can be preserved better if the Curators, Coin collectors, Numismatists have a rudimentary knowledge on the science of conservation of coins.

Technology of Coin Making

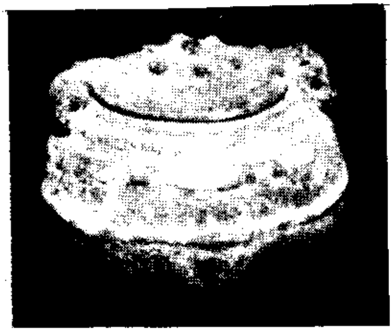
Coins were made both by punching marks on the metal and by moulding them in a mould specially made for this purpose. Some times definite weight of metal is taken and kept in between the two pieces of the die and struck with a mall on the upper die. The design or inscription is not clearly marked on such coins, as the die might not have been impressed properly. These can be studied by metallography.

Collection of Coins

Most of the coins in the Government Museum, Chennai are through the Treasure-trove Act. They are sent to the museum for examination and keeping them in the museum through purchase. Ancient people buried the coins in order to protect them keeping them either in mud pots or bronze vessels. Now we receive such burials in the form of treasures through accidental digging. In most of the river beds one can see coins after a heavy showers.

Examination of Coins

In order to conserve coins one must have the knowledge of the metals, alloys, constituents of the coins and their corrosion products. In order to find out the metallic composition, non-destructive analysis will be carried out by Weisz ring-oven technique or by non-destructive instrumental means like X-ray fluorescence analysis, electron spectroscopy for chemical analysis. The type of corrosion is studied by x-ray diffraction analysis. These studies make one to choose the correct method of conservation treatment.



Bronze Vessel to Keep Coins

Metals Used in Coins

The earliest coins, which were in use, are punch marked gold, silver and copper coins. Die struck coins of various metals are preserved in the museum. The following table tells the various metals used in making or minting of coins in India.

Metals/Alloys Used in Ancient Coins

Name of the Metal/Alloy	Constituent	Metals
White gold	Gold 90%	Silver 10%
Red gold	Gold 90%	Copper 10%
Electrum	Silver 70%	Gold 30%
Debased silver	Silver 60-90%	Copper 40-10%
Pewter	Lead 20%	Tin 80%
Coinage bronze	Copper 90%	Tin 10%
Bell Metal	Copper 78%	Tin 22%
Billon	Copper	Silver
Potin	Copper,	Tin, Lead, Silver

The following table gives an idea of the physical properties of some of the important coinage metals:

Metals	Gold	Silver	Lead	Copper	Zinc	Tin	Alumi-nium	Nickel
M.Pt. °C	1063	963	327	1084	419	232	658	1455
Sp. Gr.	19.93	10.1	11.4	8.9	7	7.3	2.6	8.9

Iron Objects

Iron is the most important and widely used of all the metals because of the abundant availability of ores and the ease with which they are reduced to iron. Earliest man-made iron artifacts are reported from Tell Chagar Bazar and Tell Asmar in Mesopotamia. These iron objects are dated to the middle of third millennium B. C. Herodotus writes that the Indian soldiers in the army were equipped with cane arrow tipped with sharp iron barbs. Alexander the Great sealed the treaty with the defeated king *Porus* (326 B. C.) with the good will token of 30 pounds of steel. The famed *Damascus steel* is of Indian origin. Kautilya's *Arthashastra* refers to large State-controlled iron mining in India during the Mauryan rule. In addition to the literary evidences cited, large number of archaeological sites have unearthed a variety of iron objects. In the Rewah Province of Central India, great heaps of cinders and slag covering many square kilometers, testify to a flourishing iron industry. In Tamil Nadu, Adichanallur, Arikkamedu, The Nilgiris, Kodumanal, Vallam etc., have brought to light a number of iron antiquities. These testify to the prosperity of iron industry that flourished during the 2nd Century B. C. to 2nd Century A. D. in Tamil Nadu.

Iron is carburized to get steel. Iron objects are made either by moulding or working. The worked objects are easily corroded and that is the reason why most of the excavated objects are almost in completely corroded form.

Conservation of Metals

Conservation of excavated and once conserved museum artifacts may be considered as one of the most important off shoots of Archaeological Chemistry.

Metallic antiquities constitute a heterogeneous though well defined group of materials, almost all prone to corrosion of one type or the other. This phenomenon results in the loss of metallic properties with the formation of mineralised incrustations due to a series of chemical and /or electrochemical reactions. The resultant disintegration/deterioration may be slow/ fast with a subtle or profound change in the appearance of the artifacts. This corrosion disease calls for the immediate attention of the conservation chemist for, the sooner the object is treated the better its chances of survival without loss of characteristics and hence their antique value.

A basic requirement for the right approach for conservation is that a maximum of information must be made available to the conservation chemist with respect to its chemical combination, physical structure, mechanical stability and last but not the least in importance the nature of corrosion products and the mechanism involved there in of the antiquity. It is only against this informative background, the conservation chemists can approach the problem in the right direction. Conservation chemistry therefore presents a complicated set of problems, both technical and aesthetic and the conservation chemist must never stray away from any one of the following guidelines:

1. The prime object of the chemist is to restore the original appearance to the maximum extent possible.
2. To use such of those conservation technique(s) to protect the antiquities from further deterioration and
3. To record the historic documents of the art and technology of the article to posterity in all its pristine form.

Hence it is of prime importance to choose a conservation technique with a view to take care to the preservation of the authentic, aesthetic and material characteristics of the antiques. In the above context it is often difficult to decide what has to be removed from the corroded objects and what to be left on it in order to restore as much as possible of its original appearance.

Corrosion from the surface to the core of the metallic objects causes considerable destruction to the original surface including its shape, colour and texture and inscription-the first three physical properties determine the aesthetic and antique values of the object. Additionally, corrosion products on the objects often become conglomerated with the minerals around them considerably adding to the general grotesque disfiguration of the artefacts.

As a rule, a detailed examination of all the corrosion and siliceous layers is absolutely essential prior to removal of anything from the surface of the objects, because, important features concerning the object and its history may oft' times be inferred from the deposits which are likely to get lost in the treatment processes. More so, knowledge of the structure and properties of deposit helps in the choice of the right approach to conservation method.

After the preliminary examination of the whole corroded object, qualitative chemical analyses are performed on the corrosion products carefully scraped out of the metal antiquities. Results often reveal, that they are closely related to some naturally occurring mineral/ore form of the metal constituents present in the alloy. Oxides, halides, sulphides, sulphates and carbonates are some of the less complex commonly encountered corrosion products formed on metallic antiquities.

Museum objects of priceless antique value on display/ preserved in stores are generally left in a relatively stable environment and consequently they are not readily vulnerable to the otherwise destructive corrosion forces of the fluctuation atmosphere. Such of those articles exposed to the atmosphere out of doors are however susceptible to corrosion at a relatively faster rate due to the adverse effects of the sun, rain, wind etc.

Excavated or treasure-trove objects brought out suddenly to the atmosphere are prone to damage and deformation on account of the sudden disturbances from their state of equilibrium with that prevalent environment in the buried condition. This may result in partial or total mineralisation within a short time depending upon the condition of the excavated objects and the prevailing new environment. Hence conservation is an important stage for all the antiquities received in the museums before display in the galleries or those to be kept in storerooms.

An in-depth knowledge of the chemistry and mechanism of the corrosion products and corrosion respectively on different metals/alloys is essential before one selects a particular conservation method.

Corrosion Products
Copper

Beginning with Berthelot, several investigators- Rosenberg, Fink, Polushkin, Collins, Caley, Plenderleith and Rutherford J. Gettens, have described the chemical nature of the layered structure on the surface of ancient artefacts of copper and its alloys and have also suggested chemical and/or electrochemical reaction mechanisms to explain the formation of several mineral products compacted on them. Some of the corrosion products on the copper antiquities are red cuprous oxide (Cu_2O), black cupric oxide (CuO), greenish blue malachite [$CuCO_3.Cu(OH)_2$], blackish green *atacamite* and *paratacamite* ($Cu_2(OH)_3Cl$), azurite [$2CuCO3.Cu(OH)_2$], *Chalcopyrite* [$CuFeS_2$], etc. The corrosion that occurs on the alloys of copper such as bronze, brass, etc., is dominated by the chemistry of copper, the major element present, in the alloy. The main corrosion phenomenon encountered in bronzes and allied materials is termed bronze disease. Bronze disease is a form of pitting corrosion where, the metal constituent(s) present in the alloy being at the lower side of the electromotive series with respect to the major metal copper is actively dissolved by the corrosive agents and the corrosion products get deposited in the pitted points.

One probable mechanism for the underground corrosion of bronze is described in which, strata of cuprous chloride, cuprous oxide, and basic copper carbonate are found in succession from the metal to the surface. The cuprous chloride is usually present at the interface between metal and cuprous oxide.

Cuprous chloride is known to reach in a reversible manner with water to form both cuprous oxide and hydrochloric acid. The hydrochloric acid is then removed from the system by reaction with metallic copper in the presence of oxygen to regenerate cuprous chloride as:

$$2CuCl+H_2O \longrightarrow Cu_2O+2HCl$$
$$2HCl+2Cu+1/2\ O_2 \longrightarrow 2CuCl+H_2O$$

The first of these reactions is caused by the second to proceed in a forward direction with the formation of cuprous oxide,

Bronze Diseased Bronze Icon

which will be added to the mass of this mineral, which is already present. As a result of the second reaction, cuprous chloride is continuously regenerated ahead of the newly formed cuprous oxide. The copper metal is correspondingly corroded away, with the net result that the layer of chloride moves steadily forward into the metal. Sometimes, the cuprous chloride oozes out from holes thus formed. This is called the weeping of bronzes.

At areas of loose overlying layers of minerals, air and moisture may enter sufficiently rapidly to convert compact cuprous chloride directly to bulky basic cupric chloride, which then breaks out, upon the surface and provides an easy-path for the entrance of yet more oxygen. The loose powder formation can also be referred to as malignant patina.

If the hydrolysis of cuprous chloride is combined with oxidation to form the basic copper (II) chloride is combined with oxidation to form the basic copper (II) chloride, $[Cu_2(OH)_3Cl]$, as

$4CuCl+4H_2O+O_2 \rightarrow 2Cu_2(OH)_3Cl+2HCl$, the reaction will proceed spontaneously but the concentration of hydrogen ion cannot increase above approximately 4X10-5M over the cuprous oxide membrane since at lower pH values, the dissolution of the basic copper chloride occurs as:

$$Cu_2(OH)_3\,Cl+3H^+ \longrightarrow 2Cu^{2+}+3H_2O+Cl^-$$

To explain this observation the following chemical equation postulated by many scientists might be invoked :

$Cu\text{-}Sn\text{-}Pb \longrightarrow Cu^{2+} + Sn^{2+} + Pb^{2+}$
(Leaded bronze)
$Cu^{+} + 2NaCl + 2H^{+} + 2(O)^{-} \longrightarrow CuCl_2 + 2NaOH$
(Cathodic)
$CuCl_2 + 2NaOH \longrightarrow Cu(OH)_2 + 2NaCl$ (Blue gelatinous)
$2Sn + O_2 + 2H2O \longrightarrow 2Sn^{2+} + 4(OH)^{-}$
$Sn^{2+} + 4NaCl + 2H_2O + 2O^{-} \longrightarrow SnCl_4 + 4NaOH$
$SnCl_4 + 4NaOH \longrightarrow Sn(OH)_4 + 4NaCl$
$2Pb + O_2 + 2H_2O \longrightarrow 2Pb^{2+} + 4(OH)^{-}$
$Pb^{2+} + 2NaCl + H_2 + (O) \longrightarrow PbCl_2 + 2NaOH$
$PbCl_2 + 2NaOH \longrightarrow Pb(OH)_2 + 2NaCl$

Patina Formation

Under conducive temperature in the presence of atmospheric air, copper reacts with oxygen, an oxidant, to form a layer of cuprous oxide, Cu_2O. The object becomes covered with the familiar brown patina of bronzes, which constitutes a protective layer conforming to the original contours of the object. This copper (I) oxide may subsequently be oxidised to form copper (II) compounds, which are characterised by blue-green colour. Basic copper nitrates, sulphates, carbonates are the end products of the continued combined effects of air, water (moisture), carbon dioxide and pollutants like oxides of nitrogen and sulphur on copper and its alloys. Such patina once formed is stable for centuries and is called *edel patina,* which imparts on aesthetic beauty to the artefacts.

Gold objects

Gold is a noble metal. If gold is pure, it does not corrode even if gold objects are found buried under the earth for a long time. Red gold, white gold, *electrum* are some of the important alloys of gold. When such alloyed objects are exposed to corrosive atmosphere the baser metals corrode first and leached out to the surface resulting in the surface enrichment of gold. For example, copper in a gold alloy corrodes first and the corrosion products cover the whole object making it to look like copper. When the corrosion products are removed, gold appears to be bright.

Gold objects, which are in contact with copper also, appear greenish-blue because of the corrosion products of copper. Such objects are treated with alkaline sodium potassium tartrate and the original appearance is regained.

Gold objects, which were buried in lime deposits, were found to be covered with calcareous materials. Such objects are immersed in a 1% solution of nitric acid, which removes the calcareous materials.

The dirt on gold objects can be easily removed by a mild detergent like *Laboline, Extran, Laboclean* etc. Cleaning with an ultrasonic cleaner with a detergent solution cleans the objects for a few minutes in a 2% caustic soda solution. Buried gold objects sometimes appear purplish-red in colour giving an aesthetic look. It is a valuable patina worth preserving but it is easily rubbed off.

Gilded objects need care while treating them. If gold coating is found over copper or bronze, alkaline Rochelle salt treatment is rewarding. But, in general mechanical cleaning with needle etc., is advisable. Gilded gold objects found darkened by soot, dirt etc., may be cleaned with the help of 5% ammonia solution.

Pure gold is very malleable. Therefore, only an experienced conservator should reconstruct crushed objects.

Silver Objects

Silver is a noble metal. It corrodes when it is buried or exposed to unfavourable environment. The normal corrosion products of silver artefacts identified are black silver sulphide, lavender silver chloride and pale yellow silver bromide. Silver objects form silver sulphide when buried underground for long time. In a museum atmosphere, they rarely change to silver chloride, but often they tarnish, indicating the formation of silver sulphide. Buried silver objects sometimes are found to be covered with copper corrosion products which is due to the corrosion products of copper alloyed with silver objects sometimes are found to be covered with sulphide. Buried silver objects sometimes are found to be covered with copper corrosion products which is due to the corrosion products of copper alloyed with silver object or due to the transfer of corrosion products from the copper container in which the silver coins are usually hoarded. Mostly silver coins are found buried in a copper container and the treasure-trove coins are usually received in the museum along with the copper containers sometimes in mud containers.

Being a noble metal, at ordinary temperature and in dry air, silver remains apparently unoxidised. However, at ambient temperature, combination between metal cations and oxygen ions result in the formation of an oxide. If the oxide assumes a similar crystalline structure to that of the metal upon which it is growing, and if it occupies a volume larger than that of the metal destroyed for its formation, it acts protectively. If the silver oxide film is produced in dry conditions at room temperature, it is in fact outstandingly protective. In the presence of moisture, hydrogen peroxide is formed on the surface. The hydrogen peroxide formed promotes the penetration of corrosive agents by introducing irregularities in the oxide structure. Chloride ions easily permeate through the oxide films peptize conglomerates of their molecules and intensify the already existing flaws, leading to the creation of numerous local cells in all crevices and abrasions of the silver layer. The exposed copper present in the object acts as an anode and the silver object acts as a cathode in which copper goes into solution forming copper (II) chloride in the chloride environment. Silver then undergoes attack by copper (II) chloride and dissolve according to the equation.

$$Cu^{+} + 2Cl^{-} + Ag^{+} \longrightarrow AgCl + CuCl.$$

Thus the corrosion mechanism of silver may be explained as detailed above.

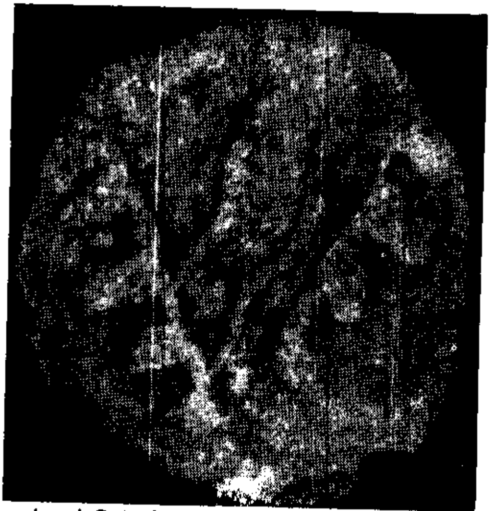
The other ruinous change of the silver objects is caused by hydrogen sulphide. It reacts with silver in the presence of oxygen as:

$$2Ag + H_2S + 1/2O_2 \longrightarrow Ag_2S + H_2O$$

The tarnishing of silver requires both oxygen and water.

Lead Objects

Lead was an extremely important material in ancient times. The Egyptians probably used lead as early as 5000 B.C. Lead was widely used by the Greeks and Romans. It has been


Lead Coin from Andipatti, Tamil Nadu

observed that in Italy, pure lead was used for most important durable materials like water pipes and the less pure lead in the making of antiquities like tokens, coins and minting die proofs. In India the use of lead was prevalent from ancient times. A lead specimen, free from silver, was found at Mohenjodaro.

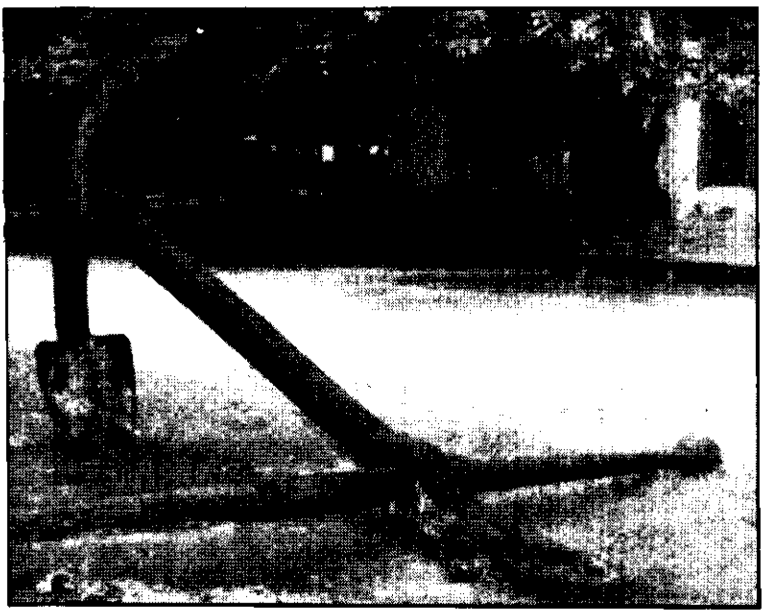
Ancient lead objects excavated from the soil are often covered with white incrustation, which is produced by the chemical action of saline matter in the soil. A wide variety of corrosion products have been identified in lead objects. They are, *massicot* (PbO), *platnerite* (PbO_2), *cerrucite* ($PbCO_3$), *hydrocerrucite* [$Pb_2(CO_3)Cl_2$], *anglesite* ($PbSO_4$), *galena* (PbS), etc. Lead objects are normally coated with a thin film of dull grey oxide; if this is pure dry air (free from pollutants) acts as a protective patina. However, this film of oxide in contaminated air is discontinuous and non-protective and in course of time, active corrosion breaks out with the formation of basic lead carbonate. This corrosion product is puffy, voluminous and loosely adherent. It is for these reasons that lead objects often suffer serious disfiguration unless the corrosion is checked in the early stages. Research has proved that pure metals are corrosion free when compared to impure metals.

When lead objects are excavated from the ground they are commonly found to be covered with a dull white encrustation, which appears to be stable; it is in such an unsightly condition and often as to be unacceptable as specimens for exhibition that the lead antiquities are received in museums. Improper storage affects lead objects.

Lead objects buried under the soil are mostly found covered with corrosion products. Their removal sometimes results in serious deformation and complete crumbling down of the objects. Such objects in near total state of deterioration should be consolidated rather than conserved, at least to restore back their gross details. However, sound objects may be subjected to conservation methods detailed earlier to restore back the hidden details.

Iron Objects

Iron is the most important widely used of all metals because of the abundant availability of ores and the ease with which they are reduced to iron. Earliest man-made iron artifacts are reported from Tell Chagar Bazar and Tell Asmar in



Iron Anchor from Sea in a Corroded Condition

Mesopotamia. These iron objects are dated to the middle of third millennium B.B. The famous Damascus steel is of Indian origin. In Tamil Nadu, Adichanallur, the Nilgiris, Arikkamedu, Kodumanal etc. excavations have brought to light a number of iron antiquities. Iron objects corrode easily, giving rise to unsightly rust that cause swelling and deformation of the decaying objects. The various corrosion products identified on iron antiquities are oxides, sulphites, phosphates, basic sulphates / carbonates / chlorides, hydroxides, oxychlorides of iron etc. Exposed monuments of iron in the atmosphere are in constant contact with oxygen, pollutants, moisture, heat, etc., and hence they are prone to chemical and physical changes. However, the wonder iron pillars at Dhar and Delhi have withstood the ravages of time due probably to their high purity iron content of 99.8% and 99.72% respectively.

Many iron objects buried under the ground are heavily materialised with only a thin metal core. Chlorides play an important role in the corrosion of iron objects. If the excavated iron objects are partially corroded by the chloride bearing corrosive agents, the chloride must be removed completely, otherwise rapid corrosion will completely mineralise the objects.

Depending upon the stage/state of corrosion, the iron objects can be classified under three categories as:

a. Slightly corroded
b. Extensively corroded but having a thin metal core
c. Grossly corroded, mineralised objects.

Bidriware

Bidriware is made out of zinc alloyed with copper, tin and lead. The name bidri was derived from a place in South India where a special earth was found, which had a chemical effect on this alloy and was used to make objects. The object, after casting and polishing, is engraved with designs to be inlaid with silver or gold wire or plate and thereafter rubbed with earth. This process gives the object a beautiful black colour, leaving the silver or gold wire shining.

The black finish is important to bidri objects. This should not be subjected to acidic or alkaline chemicals. If the inlaid silver or gold wire or sheet is separated, it should be fixed in position with adhesives like araldite.

Modern Metals in Coins

Artefacts, coins, and medals made of aluminium, zinc, magnesium, nickel etc., and their alloys form a small but significant part of the collections of objects of modern metals.

Zinc

Zinc was known as a distinct metal in India in the 14th Century AD. But, knowingly or unknowingly zinc is invariably found in all icons, artefacts and antiquities made of copper alloys even before 14th Century.

At high humidity, zinc is corroded to form zinc hydroxide [$Zn(OH)_2$] in the absence of carbon dioxide and basic zinc carbonate [$ZnCO_3$ $Zn(OH)_2$] in the presence of carbon di oxide. In the presence of sulphur-di-oxide it forms zinc sulphate. Zinc gets corroded in the presence of oils and plywood.

Aluminium

Aluminium was discovered in 1820. Aluminium is resistant to corrosion due to the formation of a protective film of aluminium oxide (Al_2O_3). It forms chloride and sulphate. Aluminium gets corroded in an enclosed environment containing urea – formaldehyde adhesive, in tropical climate.

Magnesium

Magnesium was discovered in 1808. Magnesium gets corroded and it forms hydroxide, basic magnesium carbonates [$Mg(OH)_2 MgCO_3$] and sulphates. Acids profoundly corrode magnesium and its alloys. Wood emanates gases, which corrode magnesium.

Conservation Chemistry of Metallic Objects

The two main objectives of conservation of metals are,

1. Removal of corrosion products and
2. Arresting further corrosion.

Removal of Corrosion Products

The deleterious corrosion products on metallic artefacts should be thoroughly removed in order to prevent further corrosion of the artefacts. The removal of corrosion products can be effected either by a) Physical, b) Chemical, c) Electrochemical/ electrolytic methods or d) by the combination of one or more of the above methods.

A. Physical Method

The corrosion products along with the siliceous materials can conveniently be removed physically be simple mechanical tools such as pin, scalpel, chisel, hammer, mechanically operated vibro-tool, etc. The areas exposed after the unwanted corrosion products thus removed are given a final rub with fine emery paper to bring out the inner patina layer to relief adding aesthetic beauty to the objects for certain patina layer to relief adding aesthetic beauty to the objects for certain patina can also act as a protective coat. Mechanical means of removing deposits have the advantage over chemical means in that the former methods do not introduce or leave behind any additional chemicals or products of chemical changes on the metal artefacts. Air abrasion may also be carried out. Laser beams are also used to remove the unwanted accretions.

Participants of a Training Programme Mechanically Clean an Iron Anchor

Ultrasonic method can be used to remove the extraneous siliceous matter by immersing the objects in a detergent solution contained in an ultrasonic cleaner. Vibro-tool may also be used. However, this technique calls for extreme care, for lack of it may damage the finer workmanship of the artefacts. Airbrasive can also be of use.

B. Chemical Method

Usually chemicals, which can dissolve or form soluble complex with the corrosion products, are used to remove the deleterious materials from the objects. Only mild chemicals and very dilute solutions are used to remove the corrosion products without affecting the metal beneath.

If chlorides are present in bronze antiquities, the antiquities are soaked for few weeks in an aqueous solution of sodium sesqui carbonate (equal proportions of sodium carbonate and bicarbonate), the completeness of removal of the corrosion products is indicated by the carbonate solution acquiring the faintest blue tinge. This procedure converts into oxides and / or to other harmless the metal chlorides yet protective corrosive products and thereby the metallic artefacts are protected and preserved.

Buried bronze antiquities coated with a heavy white deposits of calcareous materials such as calcium carbonate and magnesium carbonate are soaked for about a week in 5% aqueous sodium hexa meta phosphate in which the calcareous deposits are soluble.

The bronze diseased bronze or brass or copper objects may be treated with alkaline Rochelle salt solution (15gms of Rochelle salt i.e. sodium potassium tartrate, 5gms of sodium hydroxide and 80ml of distilled water). This removes completely the corrosion products of copper and the oxide layer is exposed. Red Copper (II) oxide is removed by treating with a 10% citric acid solution, but the surface is found to be rough because of pitting of the metal by citric acid. The patination will be lost by this treatment

10% ammonia is used to remove the copper corrosion products as ammonia forms a complex with the copper chloride.

A 5% EDTA solution is used to remove corrosion products.

The black silver sulphide (Tarnish) and the lavender silver chloride are removed by 10% formic acid and 10% ammonia alternatively. The debased silver objects look like copper as they are covered with corrosion products of copper. They are first treated as if they are copper objects.

Lead objects are treated with 5% acetic acid. This removes the corrosion products of lead.

Iron corrosion products are stabilized by the use of tannic acid based products.

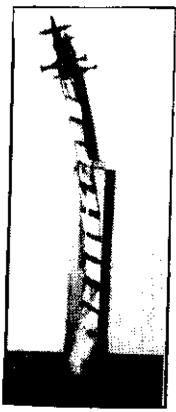
Poulticing with sepiolite may clean wax-coated iron objects.

Chemicals such as 5% phosphoric acid or thioglycolic acid can be used for the immersion treatment of the iron objects. Objects retrieved from the sea/saline soil can be boiled in a 10% solution of sodium hydroxide solution, which removes the chloride arresting further corrosion. The Sodium hydroxide should be thoroughly washed.

Ion-exchange resin treatment is yet another approach to treat especially corroded lead antiquities. The corroded lead object is placed in contact with granules of treated exchange resin (Amberlite IR120) covered with warm distilled water for about 20-30 minutes. Metallic lead is unaffected , but incrustations of lead cations are removed by the Amberlite IR 120. The Amberlite IR 120 may be regenerated and used again.

C. Electrochemical /Electrolytic Reduction

The electrochemical reduction involves the reduction of the corrosion products by nascent hydrogen evolved by the action of 10% sodium hydroxide on zinc granules/powder on the affected spots.



Sword under Electrochemical Treatment

The corrosion (oxidation) of metallic artefacts is usually an electrolytic process. The removal of the oxidative corrosion process can be effected through reductive electrolysis. The electrolytic method first developed by Finkener was widely used. It was Colin G. Fink who put it to extensive use for the restoration of bronzes in the Metropolitan Museum of Art, New York. In 1930, Paramasivan adopted this technique in the Government Museum, Chennai for the restoration of large sized South. Indian bronze icons and heavily corroded copper plates with inscriptions. This method continues to be popular even to this date by many conservation scientists for the restoration of coins and inscribed plates.

Electrolytic Cell

Reduction is usually carried out in an electrolytic cell keeping the antiquity as the cathode with two strips of iron gauze suspended on either side of the object or a cylinder of the same material enclosing the object all round, as the anode in a 5% aqueous sodium hydroxide/sodium carbonate/ acetic acid or formic acid electrolytic bath. Current is passed from a direct current supply from a 1-50 volts source and an optimum density (2 amps per square foot with respect to cathodic object) for a few to several hours, depending on the thickness of the encrustation. The corrosion products on the antiquity are reduced and removed by alternate brushing and washing until the hidden details are exposed with all its intrinsic artistic details.

Electrolytic Brushing

In the case of large sized, non-transportable bronze objects (which cannot be easily shifted from the galleries/stores to the laboratory) a localised treatment of a slightly modified electrolytic method is resorted to, with good success. The metal object affected by spot corrosion is kept as the cathode. A steel rod with a sponge head moistened with 10% caustic soda solution is connected to a 12 Volt direct current power supply and the electrolyte impregnated sponge is pressed on the affected spot and the circuit completed. Electrolytic reduction takes place and the spots get reduced to the corresponding metal. This process has been very successfully used by the author for local treatment and conservation of bronze icons, iron swords, etc. Lead coins may be conserved with graphite anode successfully.

The bronze icons, which are affected by weeping, are locally cleaned by electrolytic brushing. Since the holes found at the weeping spots are just able to take the finest needle of a syringe, the liquid collected in the holes is first syringed out. When numerous holes are present in the icon, the surface of the affected object is poulticed with moist neutral paper pulp and the same removed when dry. This procedure is repeated till the paper pulp removed gives a negative test for chloride. Silica gel may be used to absorb moisture from objects.

Treatment of slightly corroded iron objects in fairly good condition with solid core of metal is best done by electrolytic reduction. Spot reduction can be effected by electrolytic brushing or by electrolytic reduction.

Intensive washing

Intensive washing is the last step but definitely not the least in importance in conservation of artefacts; unless the treated objects are washed completely free from the residual chemical(s) left behind on the objects, they will once again react with metal and the corrosion cycle will be repeated again. Therefore, washing should be intensive and thorough in the final stages especially with methods involving chemical treatment. The last residual salts in the treated objects are best eliminated by prolonged soaking of the objects in distilled water or the process may be speeded up by using hot water. This process may be repeated to ensure complete removal of chemicals. R.M. Organ has successfully carried out this intensive washing technique with distilled water by alternate heating and cooling.

Consolidation and Protective Coating

The metallic antiquities, which are very fragile and highly mineralised, need to be packed up with wax/resin. This process is called consolidation. Consolidation can be done with 10% wax dissolved in benzene or by vacuum impregnation. A 2-3% polyvinyl acetate in acetone, toluene or acetone-toluene mixture can either be coated on the object or vacuum impregnated. In the case of fragile bronzes, the missing corroded portions after treatment are filled and modeled with resin like M-seal or Paraloid B72 mixed with suitable pigment.

Arresting Corrosion

1. Stabilization of Highly Corroded Objects

In most of the excavated and treasure-trove objects, it is seen that the corrosion has proceeded to an extreme stage where very little metal is left intact. In such cases, objects can best be conserved by stabilising the corrosion products formed.

Spots of bronze disease formed over protective layer of patina may be mechanically removed. The pits found are then filled with a fine paste of silver oxide (in alcohol/water). Insoluble silver chloride thus formed seals off the underlying harmful effect of copper (II) chloride arresting further corrosion. Sodium sesquicarbonate solution dissolves the copper (II) chloride (bronze disease) without affecting the copper (II) carbonate (protective patina). Zinc dust in place of silver oxide may be used effectively.

Therefore prolonged immersion of the bronze-disease affected antiquity in a solution of 10% sodium sesquicarbonate removes the deleterious chlorides and stabilises the carbonate patina formed on copper alloy antiquities.

Benzotriazole (BTA) in water or alcohol forms a complex with cupric chloride and oxides. This inhibition procedure can also be adopted to arrest further corrosion. Benzotriazole in water is preferred to benzotriazole in alcohol in the cases of antiquities with thick layer of bronze disease as the former slowly but surely penetrates into the core of the metal-the evaporation of water mixture being slow compared to benzotriazole-alcohol treatment. This is the most effective method for the conservation of copper and bronze archaeological antiquities affected with bronze-disease.

One of the methods of preventing "bronze disease" in antiquities is to maintain the antiquity in a dry atmosphere (45-60% R.H.). Under these conditions the spreading of further corrosion is arrested. Therefore, air conditioning should be round the clock for the safety of metal objects especially bronze objects.

Even wood emanates some acid fumes and therefore silver objects displayed inside the cases are affected. Zinc oxide globules are kept in the cases to absorb the hydrogen sulphide vapours thereby tarnishing is averted.

Poulticing is adopted to remove salts from iron objects since iron rusts fasts. The rusting may be stopped by applying a water repellent on the surface of the objects. Besides wax, some consolidants like poly vinyl acetate, Paraloid B72 or varnishes can be applied on the objects.

Restoration

The Concise Oxford Dictionary gives the meaning for repair as to restore to good condition, to renovate, the mend, by

Bronze Icon Before Restoration

replacing or refixing parts or compensating loss and is a process, which is as old as man the toolmaker. Ancient man learnt how to make useful things out of the natural materials around him, he had to repair those objects when they break or wear out. A good example is the Bronze Age Dowris bucket in the British Museum, London. All utilitarian objects are likely to be repaired, if this proves cheaper than buying another one. Riveting is a method of repair which applies to metal objects. When a non-utilitarian and purely

Bronze Icon After Restoration

decorative object is damaged, or perhaps just looking shabby, it is more appropriate to call the mending process restoration. The Concise Oxford Dictionary defines as bringing back to original state by rebuilding, repairing, repainting, emending etc. The bronze head of Minerva in the Roman Baths Museum at Bath, which can be shown by a microscopic cross section through a minute fragment of the surface to be covered with six separate layers of gold, must have been regilded several times tin antiquity. The process of regilding has been described by Oddy as restoration. Restoration rather than repair started increasing as the foundations of the conservation profession began to be laid. Restoration is one of the terms quite often mentioned. All direct actions taken to bring the objects to the nearest original form and conditions is termed as restoration. In this the later additions are removed and new materials are not added. The pristine form is maintained.

There are many acts of restoration depending upon the condition of the object. The various terms are dowelling, mending, repairing etc.


Dowelling of a Bronze Icon

Dowelling is a process of joining broken pieces. In case of bronze icons, the joint is made by bronze or brass nails. If it is bigger object, it may be difficult to carry out the joining work. Holes are made on both the sides of the object and a brass nail sharpened at both the ends is inserted in the drill hole and an adhesive is used to fix the broken pieces.

In case of missing portions, polymers may be very successfully used. While polymers are used, pigments are also added to give the suitable colours. In the Government Museum, Chennai some of the objects are restored with the help of polymers added with suitable pigments.

Conservation and Excavation

Conservation principles have to be followed in the conservation site including the selection of sites for excavation, site maintenance, conservation of antiquities immediately after the excavation etc. Soon after the excavation, silver and gold objects cannot be identified if they have the impurity copper and they look like copper objects. Silver objects will appear black or red. They should be packed in well padded boxes. Iron objects should be dried under shade to avoid corrosion. Silica gel may be used when packing is done. For lead objects acid free tissue paper may be used for lead objects.

Conservation and Storage

For providing long life, the storage also should be taken care off. There is natural tendency to relax conservation vigilance when the museum objects are out of sight in storage or in vaults.

The basic principle of storage is to keep the objects in a physically secured environment and yet to permit ready access for inspection before their removal to the galleries or other locations. The relative humidity, temperature should be taken care off while the metal objects are in the storage too. While air conditioning the storage or the gallery, provisions should be given for 24 hour air conditioning, removal of dust and other acidic oxides.

Authenticity of Metal Objects

Radiology is one of the fundamental non-destructive methods of investigation and examination of works of art such as metal objects, paintings, paper materials, wooden objects, ceramics etc. It has been used in the past and is used in the present in the detection of forgeries of the original works. When X-rays are allowed to fall on an X-ray film through the object to be examined, a shadowgraph is formed on film depending upon the structure of the object. The latent image is developed, like photographic film to obtain the image of the inner structure of the object called radiograph. In the case of metal object, the radiograph registers its various parts. This information is used to conserve and to identify the object. Radiography could help in characterisation of these art works in order to finger print them for legal purposes.

Bronzes Icons Waiting to be Radiographed

Finger printing of art objects and antiquities of all materials could be done, if some documentation technique could be used such as Macro photography, Infrared Photography, Radiography. Analysis of elements through classical as well as sophisticated instrumental methods will reveal the composition of the bronze icons. These records should be kept as secret. Otherwise the culprits will use this data and fake objects will be produced in plenty.

Since faking of objects are prevalent now-a-days, it is obligatory in the part of those who protect the antiquities and works


Bronze Icon


Radiograph Showing the Voids

of art from making copies. The authenticating data should be made available to the art critics, archaeologists when such situation arises for the authentication of objects.

Conclusion

Conservation aspect of metal is very important in all stages from collection to handling, transportation, display, storage etc. There fore one who involves in the conservation should be aware of all facets of conservation. If any doubt is there, then the person who conserves or restores the metal object should consult the experienced conservator before the conservation or restoration work is started. In some cases not handling the metal object will be safer as in the cases of some of the bronze objects in the Government Museum, Chennai.

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Chemical Conservation and Research Laboratory

History of the Laboratory

With the valuable collection at the Government Museum, Chennai, it was felt necessary to treat the bronzes disfigured by corrosive crusts in order to expose the decorative details and to eliminate the bronze disease, which brought in added deterioration. As a result of the discussion with various chemists, the electrolytic restoration of bronzes was started in the museum. The Chemical Conservation and Research Laboratory in the museum owes to the scientific vision and foresight of Dr. F. H. Gravely, Superintendent of the Government Museum, Chennai in the early 1930s. Dr. S. Paramasivan was appointed as the Chemist in 1930. He was very active both in conservation and research activities. Besides the treatment of bronze objects, ethnological, prehistoric and numismatic objects were treated. In 1935, the Government Museum, Chennai was also of help to the Archaeological Survey of India in the examination of wall paintings at Tanjore, Sittannavasal etc.

In 1937, a separate Chemical Conservation Laboratory Block (Old Chemistry Block) was built, being the only one of its kind in India. A two storied building for the laboratory was constructed in 1963. In 1997, the Chemical Conservation and Research Laboratory was recognised as a research institution to conduct research leading to Ph. D. Degree and Dr. V. Jeyaraj, Curator of the Laboratory has been recognised as a Research Supervisor by the University of Madras. At present one part-time scholar is working under him.

Research Activities

One of the foremost activities of the laboratory is to conduct research in conservation and materials of the past. In the beginning much research was conducted by Dr. S. Paramasivan, the first Curator of the Laboratory on paintings and metallic antiquities. The research findings were published in leading scientific journals both in India and abroad. The research activities continued successfully by the Curators of the Laboratory till date. At present research projects such as *Fingerprinting of South Indian Bronze Icons, Holographying Museum Antiquities, Survey of Monuments in Tamil Nadu, Conservation of Metallic Antiquities* etc., are under progress.

Conservation Research Activities

The Laboratory is interested in the conservation research in order to find out new techniques and materials in collaboration with leading research institutions such as Indira Gandhi Centre for Atomic Research, Kalpakkam; Indian Institute of Technology, Chennai; Anna University, Environmental Engineering wing of the CSIR, Chennai and foreign institutions like the Australian Museum Sydney and Getty Conservation Institute, Canada. The laboratory was recognised as a research institution in 1997 by the Madras University to conduct research leading to Ph. D. Degree. Dr. V. Jeyaraj, Curator of the laboratory is a recognised guide. At present one part time research student is working on a research project on Conservation of Metal Antiquities.

Publications

The publication of this laboratory from its inception is commendable. Leading national and international journals such as Indian Academy of Sciences, The Current Science, Conservation of Cultural Property in India, Studies in Conservation, Technical Studies etc., published the out come of the research works. Besides hundreds of research and popular articles many books and bulletins have been published. Handbook on Conservation in Museums, Care of Museum Objects, Conservation of Archival Materials, An Introduction to the Chemical Conservation and Research Laboratory, Care of Archival Materials, Conservation of Temple Objects, Conservation of Cultural Property in India, Care of Paintings, Conservation of Cultural Heritage etc., are some of its publications. Many conservation reports have been prepared by the successive curators regularly through out the career of this laboratory. The present Curator has prepared about thirty reports.

Training

In order to disseminate the expertise of the laboratory, in 1974, a refresher course on *Care of Museum Objects* was started. It was well received by professionals and students of museum related subjects. In 1995 a course on *Care of Temple Antiquities* was conducted for the Executive officers of the Hindu Religious and Charitable Endowments Department. In 1997, a course on *Care of Archival Materials* was conducted exclusively for the Archivists. Students from the College of Arts and Crafts were given practical training for a period of 3 months on the conservation of museum objects especially on paintings. Slowly this course was named as the course on Care of Art Objects. Capsule course on Conservation of Cultural Heritage is the latest course. Besides these training programmes, to the school and college students is given both in Chennai and districts on Care of Cultural Materials and Preservation of Monuments. It has entered its name as the number one in the field by introducing *Internship Training* for a period of one year.

Conservation Services

Even though the strength of the staff in the Laboratory is very small, the Laboratory has extended service to the public and other institutions interested in the preservation of objects of the past at nominal charges. The laboratory is not able to meet the requirements of the museum as well as the outside demand due to want of staff in the laboratory. On request the Curator delivers lectures on conservation in order to popularise the subject. It is proposed to have regional laboratories in Tamil Nadu.

Conservation Gallery

For the first time in India, the Chemical Conservation and Research Laboratory of the Chennai Museum has set up the Chemical Conservation Gallery in order to educate the visitors on the preservation of the cultural and artistic heritage of our country.

Staff

The Chennai Museum is a multipurpose museum having over one-lakh objects and about 5% of them are in need of conservation treatment. At present only four members of staff man the Laboratory. One volunteer and three research scholars are helping in the laboratory activities.

A Pioneering Museum Laboratory committed for

- Conserving the museum ojects under the Department of Museums.
- Research in conservation techniques and ancient technology.
- Training people in conserving the art, cultural and natural heritage for posterity.
- Providing research facilities leading to Ph.D. Degree under the University of Madras.
- Internship training.
- Conservation consultancy services.

Publications of this Laboratory are

Hand book on Conservation in Museums, Care of Museum Objects, Care of Archival Materials(Tamil), Introduction to the Chemical Conservation and Research Laboratory, Conservation of Cultural Property, Restoration of Paintings from Madras Christian College, Care of Paintings etc and brochures.

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