TECHNICAL SECTION

In this section of Ancient India *it is proposed to publish from time to time notes of a technical character for the information of archaeologists in India. Future issues will include notes on archaeological photography, methods of excavation, soil-analysis, and other matters relating to archaeological technique. The present note is contributed by the retired Archaeological Chemist to the Archaeological Survey, whose experience of chemical conservation in India is unique.*

NOTES ON THE PRESERVATION OF ANTIQUITIES IN THE FIELD

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PART I—TREATMENT

1. Many antiquities discovered during excavations are found to have undergone alteration or deterioration as a result of the chemical and physical changes which have taken place in them during the long period of their burial in the soil. Frequently, their original form and details are obscured or obliterated, and the fabric itself is considerably weakened. The nature and extent of these transformations depend on the composition of the material, character of the soil, and age of the site. Even after exhumation there is risk of further deterioration under atmospheric influence. Some objects begin to disintegrate soon after exposure to the air, others may remain apparently unaffected for weeks or longer; but once the signs of deterioration manifest themselves, further destructive changes proceed apace. It is, therefore, very important to undertake suitable preservative measures without any unnecessary delay. Moreover, before an object can be studied properly, its original form and details must be restored as far as possible. For both these purposes various chemical and mechanical treatments are necessary.

2. The methods used for the restoration and preservation of antiquities of various kinds differ according to the nature of the material and the state of preservation of the objects. In the simplest cases mere washing with plain water is all that is necessary, but oftener complicated chemical or electro-chemical treatment, besides skilful manipulation and repair, is called for. In the field, only the simpler processes should be attempted. All problems requiring sound chemical knowledge or objects demanding expert treatment should be referred to the Archaeological Chemist of the Archaeological Survey of India.

3. For the purpose of preservative treatment, antiquities can conveniently be grouped as follows:—

A. *Siliceous and calcarious materials* :—terracotta or pottery, stone, faience, stucco, gypsum, glass, enamel and minerals.

B. *Metals*:—iron, copper and its alloys, lead, silver and gold.

C. *Organic materials* :—wood, paper, birch-bark, linen, silk, horn, leather, bone and ivory.

A. Pottery, Stone, Faience, etc.

4. Of all the antiquities found during excavations in India, objects of terracotta or pottery are the most abundant and well preserved; but being porous they are impregnated with salts derived from the soil. Variations in temperature and the humidity of the atmosphere cause these salts (chlorides, sulphates and sometimes nitrates, alkalies, lime and magnesia) to crystallize out or to go into solution again within the pores. The repetition of these processes causes the disintegration of the objects. It is therefore important that the objects should be freed from the injurious salts immediately after their examination, by repeated steeping in plain water. This simple treatment is applicable to all the objects belonging to group A above.

5. Before an object is steeped in water, it should be carefully ascertained that this treatment will not harm it in any way. The best plan is to place a few drops of water on the object and see if they produce any harmful effects. All objects which are likely to be injured by contact with water should be sent to the Archaeological Chemist for necessary treatment.

6. The *steeping process* is as follows:—

Very small antiquities are washed by suspension in deep glass or porcelain vessels containing water. Ordinarily the steeping is carried out in galvanized iron tubs or tanks of suitable sizes and provided with a wooden grating which rests firmly half-way down the sides of the vessels. The objects (which have already been marked with Brunswick black paint) are placed on the wooden grating and the vessel is flushed with water, covering the objects entirely. A careful record of the contents of each tub is kept in a note-book. The water used should be free from saline impurities. It is not generally possible on sites like Mohenjodaro and Harappa, where the soil is heavily charged with salts, to get sufficiently pure water for this purpose. Therefore, arrangements should be made at the outset to get all available supplies of water chemically tested for their purity by the Archaeological Chemist, and the purest one should be utilized for this purpose.

After the objects have soaked for a day or so, they are taken out, one by one, freed from mud and incrustations with the aid of a knife or brush, and immersed again in a fresh supply of water. Hard calcareous incrustations can be removed by immersion in or application of 3 per cent. muriatic acid. Gypsum crystals generally fall off, or can be chipped off, in the course of the steeping, but difficult cases will require burning treatment in a muffle-furnace. Whether these side-treatments are necessary or not, the steeping-water is changed daily in the first week, twice in the second, and weekly subsequently.

The progress of the washing operation is judged by testing the wash-water chemically for its salinity. It is generally sufficient to test for the chlorides only by silver nitrate solution,[1] as these are invariably present with other salts in the soil. The silver nitrate test is carried out thus:—

Two clean test-tubes of the same size are half-filled, one with pure water from the supply and the other with the wash-water. To each of these tubes are added ten drops of silver nitrate solution and the tubes are shaken. A white precipitate or milkiness is produced which varies with the amount of the chlorides present in the water. The milkiness produced in the supply-water should be slight. In the first week the difference in the milkiness is very marked, but it becomes less subsequently, indicating the gradual elimination of the injurious salts. The washing is continued until the milkiness produced in both the waters is the same. This signifies that the objects have been washed free from the salts. If the objects were charged heavily with sulphates, the washings in the final stages should also be tested with barium chloride solution.[2] A white precipitate indicates the presence of sulphates. For objects of special value, a final washing should be done with distilled water.

When the objects have been freed from the salts, they are dried. Large objects are dried by exposure in the air but small ones should be dried in a hot-air oven, at 80°–100°C., for a few hours. Subsequently they are repaired or impregnated, as necessary.

Special cases.—Ordinary pottery and terracotta stand the washing treatment well, but special precautions have to be taken if these objects are covered with painted designs or colours. In such cases the surface should be freed carefully of all adhering mud, etc., by brushing, and the painted designs coated with 5 per cent. vinyl acetate solution in order to fix the colours before placing the objects in water.

7. Unbaked clay obviously cannot withstand the action of water. It should be allowed to dry in the shade and be impregnated with 10 per cent. vinyl acetate solution or hard paraffin wax which is melted and applied hot by means of a brush. If the object is charged with salts then the best plan is to keep it in a desiccator jar; or it should be baked and thus rendered fit for steeping in water to eliminate the salts.

8. It should be noted that limestone, marble and certain other varieties of stone are affected by acids. Gypsum and alabaster are slightly soluble in water, but this drawback can be remedied by the use of water saturated with calcium sulphate for the steeping operation. This can be prepared readily by shaking plaster of Paris in a tub of water, allowing the surplus plaster to settle down and using the supernatant water.

9. Heavy stone sculptures require several months or even longer for the complete elimination of salts by steeping. Therefore, it is more convenient to treat them by the *paper-pulp method* which is carried out as follows:—

Sheets of paper-pulp are torn up into small pieces and soaked in a tub of hot water for 24 hours. The mass is stirred well by means of wooden sticks until it is thoroughly disintegrated and assumes the consistency of thin porridge. Handfuls of the pulp are taken out and applied to the salt-affected surface until a coating ½ inch thick is built up all over it. The pulp is allowed to dry completely in the shade, when it is removed and

[1] The silver nitrate solution is prepared by dissolving 5 gms. of silver nitrate crystals in 500 c.c. of distilled water followed by 10 c.c. of strong nitric acid. This should be kept in a brown stoppered bottle.

[2] Barium chloride 25 gms., distilled water 500 c.c., hydrochloric acid 20 c.c.

a fresh coating is applied again to the surface. This process is repeated until a specimen of the dried pulp is found free from salts. This is ascertained by shaking the specimen with distilled water in a flask and testing the clear extract by the silver nitrate test.

10. *Repairs and impregnation after treatment.*—The materials generally employed in our laboratories now for the repairs and impregnation of pottery and terracotta are shellac and vinyl acetate resin. The shellac should be of the best orange flake quality and is dissolved in rectified spirit to form a thick solution. The shellac solution should be applied to both the edges by means of a small pointed round brush, and the excess squeezed out by pressing the parts together. The joint should be cleaned up immediately and the object left to dry in a suitable position so that the parts do not tend to fall apart in the meanwhile. A wide basinful of sand is handy for this purpose. Coarse pottery with worn edges can be repaired better by the use of solid shellac. The edges should be rendered sufficiently hot (by passing over a spirit flame) before the application of shellac. For the restoration of large vessels much experience and skill are necessary.

Vinyl acetate resin should be dissolved in a mixture of alcohol (rectified spirit) and toluene (50 : 50). 20 per cent. strength serves as a cement, but 5 and 10 per cent. solutions are required for the impregnation of decayed objects.

Repairing stone objects.—Small stone objects can be repaired by the use of shellac or vinyl acetate cements. Heavy objects of stone can be joined best by Sorel cement, which consists of (*a*) calcined magnesia and (*b*) concentrated solution of magnesium chloride, sp. gr. 1·2. These ingredients, (*a*) and (*b*), are mixed, when required, together with 2 to 4 times powdered stone and applied to the broken faces. The object is then held together firmly for two or three days to allow the cement to set hard.

B. Metals

11. The treatment of metallic objects is a complicated problem requiring both chemical knowledge and considerable practical experience. A few of the simpler and safer methods are, however, given here and may prove handy to the excavator.

12. *Copper and its alloys.*—An efficient and safe formula for the cleaning of copper and its alloys is the following:—

Tartaric acid	..	1 part.
Caustic soda	..	1 part.
Water ..	..	10 parts.

The objects should be kept in this mixture until all the green incrustations have been dissolved away, leaving the liver-red core behind. They should then be washed thoroughly in several changes of water, until free from chlorides (as found by the silver nitrate test), and finally coated with 10 per cent. vinyl acetate solution. Completely oxidized coins should, at the outset, be left in 10 per cent. sodium metaphosphate solution until free from calcareous matter. Sometimes this is sufficient to reveal the inscription. Otherwise, treat with the above-mentioned tartrate mixture diluted to half the strength. Finally wash well, dry and coat with 10 per cent. vinyl acetate solution.

13. *Silver.*—Coins and objects of silver debased with copper can be cleaned by 3 per cent. sulphuric acid until free from all red spots of copper oxide. Finally the coins are brushed and washed well in water. Silver objects and coins of the purer metal which are oxidized superficially can be cleaned by immersion in dilute ammonia or dilute formic acid. Or, they should be wrapped up in zinc sheet and suspended in water acidified with a few drops of acetic acid for a couple of hours.

14. *Iron.*—Objects of iron which retain most of the metal in the unaltered condition (as revealed by filing or being strongly attracted by a magnet) can be cleaned by electrolytic reduction. This can be carried out readily by wrapping the objects with strips of zinc sheet and immersing in 5 per cent. caustic soda solution contained in a glass vessel. After about six hours they are freed from the zinc and placed in 2 per cent. dilute sulphuric acid for a few minutes to dissolve the adhering zinc oxides. Wash well until free from chlorides [1] and dry in an oven at 80°C. Finally they should be coated with bakelite varnish or 10 per cent. vinyl acetate.

Iron objects in an advanced state of oxidation cannot withstand the electrolytic reduction. They should be kept in 5 per cent. caustic soda solution for about a week in order to decompose the injurious chlorides, followed by thorough washing with plain water until the washings are free from chlorine.[1] All the superfluous

[1] As proved by the silver nitrate test.

incrustations or oxides should be ground off carefully by the aid of carborundum files and blocks; but the surface will have to be finished properly in the laboratory, where an electrically-powered lathe fitted with a flexible shafting and small grinding wheels should be available.

15. *Lead.*—Objects of superficially oxidized lead can also be cleaned by the electrolytic reduction method mentioned above; but the washing should be done with freshly boiled water, and vinyl acetate or wax should be employed for coating them. Lead should be stored in air-tight metal containers or stoppered bottles.

16. *Gold and electrum.*—Washing with plain water is generally sufficient for these objects, but any obstinate stains or incrustations can be freed by immersion in strong hydrochloric acid.

Important note.—It is necessary to point out that the treatment of metallic antiquities should be undertaken without delay and the Archaeological Chemist should be asked to re-examine the articles which have been treated at the site, so that he may be in a position to carry out any further scientific treatment that is called for. In saline areas the copper and iron are invariably charged with unstable chlorides which can be eliminated only by careful chemical treatment. Cases have been observed where such objects have remained unaffected for several years but suddenly serious disintegration has set in due to atmospheric action. When it is necessary to store away such antiquities for some considerable time, the safest plan is to keep them in air-tight metal containers with the lids sealed up with wax and along with some fresh quicklime to keep the contents quite dry. These changes cannot start in the absence of moisture. Completely oxidized metallic objects should be passed on to the Archaeological Chemist for necessary treatment.

C. Organic Materials

17. *Bone and ivory.*—Objects of bone and ivory are generally found in a very fragile condition and disintegrate rapidly on drying. In a saline area these objects may be reduced to powder in a day or two after their excavation. It is, therefore, necessary to strengthen them *in situ* and carry out their treatment immediately. Better-preserved objects should be secured at the outset by winding a thin cotton string repeatedly all round them (to prevent splitting or any loose fragments from falling off) and immersed in water to wash out the salts completely. Then dry in the hot-air oven and impregnate with 10 per cent. vinyl acetate solution. The objects are wiped clean and allowed to dry overnight. The cotton-string windings and excess of the preservative are now removed by carefully moistening with a little toluene, and the surface freed of any adhering incrustations by scraping with a knife or file.

18. The proper handling of *skeletal remains* requires some experience and careful manipulation. In the case of burials all the bones have to be exposed completely along with the associated pottery, etc.,[1] and kept undisturbed until photographs or diagrams have been prepared. Therefore the bones will have to be strengthened *in situ* immediately after their exposure, by the application of 10 per cent. vinyl acetate or thin shellac solution. When the soil is excessively saline, the bones should be treated with paper-pulp (to remove the salts) before impregnation with these preservatives. When the necessary records and photographs have been taken, the bones will have to be strengthened further by pasting strips of paper or linen over them; otherwise, they are liable to break up when lifted from the ground. The other side of the objects should be treated similarly after their removal.

Thin bone or ivory specimens will need a sufficiently strong support to prevent damage. Therefore further reinforcement may have to be provided by means of plaster of Paris, with wooden bars embedded in it.

19. *Textiles, paper, etc.*—Textiles and paper should be freed from injurious salts by pressing between wet sheets of blotting paper several times; while adhering mud, etc., is removed simultaneously by means of a soft round brush.

20. *Old birch bark* can be rendered pliable by steaming and this can be done by suspending it (by means of a wire gauze stirrup) in a tall vessel in which water is kept boiling. After two minutes the specimen is taken out and immediately pressed flat between two sheets of blotting paper. When dry, impregnate with 10 per cent. vinyl acetate solution.

21. Objects of *wood* are generally found in a highly decayed and fragile condition. The utmost care is necessary in drying damp wood freshly dug from the soil as it is liable to split, warp, or be destroyed altogether on exposure to the air. It is, therefore, advisable to embed the specimens in a thick layer of wet sawdust or moss

[1] To preserve the pottery against disintegration due to the presence of salts, it should be coated freely with glycerine and water (1 : 1 mixture).

and send on to the Archaeological Chemist immediately for suitable treatment. Wood from saline areas must be washed or treated with paper-pulp immediately for the elimination of the salt. Dry wood should be impregnated with 10 per cent. vinyl acetate or hard paraffin wax.

22. *Fumigation.*—All objects of organic origin must be fumigated with thymol or carbon disulphide to destroy bacteria or insects that might be present in them. They should be stored in air-tight containers with some para-dichlorbenzol crystals.

PART II—EQUIPMENT

List of chemicals, etc., required for an archaeological field laboratory at a major excavation

Paraffin wax, 60°C.	10 lbs.
5% Vinyl acetate solution in alcohol plus toluene (50 : 50)	2 gals.
10% do. do.	2 gals.
20% Vinyl acetate solutions in toluene	500 c.c.
Alcohol (rectified spirit)	1 gal.
Toluene	1 gal.
Shellac, orange flake	2 lbs.
1% Silver nitrate solution plus 5% nitric acid	500 c.c.
Caustic Soda (flake)	7 lbs.
Zinc sheet (very thin)	2 lbs.
Zinc granulated	2 lbs.
Quicklime (in air-tight container)	4 lbs.
Sodium metaphosphate	2 lbs.
Para-dichlorbenzol	1 lb.
Paper pulp	20 seers
Thread, cotton reel	6
Cotton wool rolls	6
Sponges	2
Pincers	2
Needles, 3"	4
Penknives	4
Scissors, 8"	1
Files, assorted	3
Plaster of Paris	10 lbs.
Muslin	10 yds.
Gunny cloth	20 yds.
Gunny string	2 lbs.
Carborundum file and blocks rectangular (fine and medium)	4
Oil stove (Primus)	1
Spirit lamp (brass)	1
Spirit stove	1
Beatrice oil stove	1
Saucepan with handle, iron, dia. 7"	1
Iron stand tripod, round top, ht. 8", dia. 6"	2
Automatic water still (for distillation of water)	1
Brushes, nail, hair	12
Brushes, fibre	12
Brushes, flat, paint, ½", 1"	6 each
Brushes, round, paint, dia. ½" and ¼"	6 each
Brushes, round, paint, small	3
Hot-air oven, copper, 10" × 12" × 10", with one wire gauze shelf	1
Balance, weighing, sensitive to second decimal place	1
Weights in box: 50 gms. to ·01	1 set

Evaporating basins, porcelain, dia. 3", 4" and 5"	3 each
Test-tubes, glass, 6"×¾"	12
Test-tube stand (wooden) for 12 tubes	2
Glass pipette, 25 c.c.	2
Glass cylindrical jars stout with ground top, ht. 8", dia. 3"	3
Glass cylindrical jars stout with ground top, ht. 12", dia. 4"	4
Glass cylindrical jars stout with ground top, ht. 15", dia. 4"	2
Glass test-tubes with hole ½" at bottom and wire hook at top for suspension, dia. 1½", 1-10"	24
Measuring cylinders, graduated, 500 c.c.	1
Measuring cylinders, graduated, 10 c.c.	1
Rectangular glass jars (battery)	4
Bottles, wide-mouthed 16 oz. (with cork)	4
Bottles, narrow-mouthed, with glass stopper, 1000 c.c.	3
Bottles, narrow-mouthed, with glass stopper, 600 c.c.	3
Cups, China, dia. 3"	3
Cups, China, dia. 5"	2
Cups, China, dia. 8"	2
Spatula, iron 9"	2
Spoon, iron, 6"	1
Tub galv. iron, deep pattern, with wooden trellis partition to fit half-way down	4 sets

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