MATHURA REFINERY CAUSING POLLUTION HAVOC TO THE TAJ MAHAL

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Abstract

India's white marvel, the Taj Mahal , is slowly turning brownish-yellow because of air pollution, says an Indo-US study which also identifies the pollutants responsible for the effect. It says Taj is changing colour due to deposition of dust and carbon-containing particles emitted in the burning of fossil fuels, biomass and garbage. The study confirms what has been suspected for long — that Agra's poor air quality is impacting India's most celebrated monument. Results indicate that deposited light absorbing dust and carbonaceous particles are responsible for the surface discolouration of the Taj Mahal," the study concludes.

INTRODUCTION

Since 2008, ASI has been trying to fight the yellowing of the monument by giving it a clay pack treatment using the lime-rich Fuller's earth (Multani mitti) to clean the marble surface. Researchers are now keen on studying the efficacy of this method and finding ways of improving it.

The Taj Mahal is turning yellow mainly due to these reasons: air pollution, discoloration of marble due to oxidation of its constituents, environmental neglect and wear and tear caused by millions of tourists who visit it every year.

The Taj Mahal is one of the most beloved monuments in the world. However, its pristine white color seems to be in danger as a result of human excesses. How is it that this monument, which has withstood the test of time, is starting to degenerate in recent years?

If you want a simple answer, you only need to know a single word – pollution. However, it's a little more complicated than that. Different analyses have pointed at different culprits, ranging from algae and dirt to the resin applied on the Taj Mahal to preserve the monument. In the 1980s, the emission of sulphur dioxide was blamed as the main antagonist in this story, but the more we investigated, the more varied the conclusions appeared to be. With that in mind, let's try to break down the reasons behind the yellowing of one of the world's seven modern wonders(1)

Natural Causes

The Taj Mahal is, after all, a 360-year-old monument, so some discoloring is to be expected. Marble does not exist in a pure form, so the marble in the Taj Mahal is full of minerals which become oxidized over time. Oxidization leads to the browning of these minerals, resulting in brown splotches on the beautiful mausoleum. Rain also adversely affects the monument, slowly weathering it down, leading to chipping and cracking. Another material, iron, was used by the Indian government for work on the Taj, which could be an explanation. Iron dovels were installed to repair the marble slabs on the building. The iron in these dovels naturally became rusted, and a new layer of this rust was then deposited onto the marble of the Taj.

Tourists

One potential cause that hasn't been looked into as much is the tourists themselves. The Taj attracts a huge number of visitors each year. In 2013, the footfall for this edifice was 6 million! On some days, the Taj Mahal receives more than 50,000 people who want to marvel at the architectural masterpiece! Such a large number of people trotting and trudging around this marble wonder obviously causes some amount of wear and tear, right?

MATHURA REFINERY CAUSE

At a time when the improvement of environment in the Mathura Agra, Fathehpur Sikri – Bharatpur complex is seriously attempted not only to earn more foreign exchange but also to create more employment potential, through improved tourist trade, the Union Ministry of Petroleum is planning for negative development of this region through most improper siting of a six million tonne oil refinery up-wind of Agra and in close proximity to many tourist and pilgrimage centers of international fame. The Mathura Oil Refinery (1975) discharges (2), perhaps, 100 tonnes of Carbon-monoxide, 60 tonnes of sulfur-di-oxide, 50 tonnes of Hydro-carbons, 4 tonnes of Oxides of Nitrogen, 3 tonnes of sulfur trioxide, 2 tonnes of Aerosols and 10 tonnes of particulates into the atmosphere everyday. Most of these gaseous pollutants will get converted into acids and travel towards Agra for most of the time and cause serious Air pollution problems which result in slow but sure discolourisation and decay of most of the historical monuments in the region(3)

Among the many historical, sacred and enhanting monuments that will be slowly but surely destroyed by the air pollutants from the up-coming oil refinery are: Taj Mahal, Agra Fort, Itmad-ud-daullah, Jami Masjid, Tomb of Salim Chisti panch Mahal and other places at Fatehpur-sikri, Aurangazeb's Red stone Mosque, Dwarakadish temple, Gita Mandir and Jama Masjid of Mathura, Govinda Deva temple of Vrindwan and the up-coming massive magnificient Rehaswami marble structure at Dayalbagh.

When ecologists raised many objections about the potential pollution threat from this refinery, the Government of India consulted some of their own officers who are experts in fields other than Environmental conservation(4). On the false assurances given by the Pseudo-environmental experts they started the work on the Mathura Refinery. When the Members of Parliament raised serious doubts about this refinery, the Government appointed another Expert committee, again with most of their officers who are experts in fields other than Ecology and Environmental conservation. However at the request of this Committee, the Indian Meteorological Department and TECHNECO experts of Italy prepared technical reports on the dispersal of sulfur-di-oxide from the Mathura Refinery and its impact on Taj Mahal(5).

TYPES OF AIR POLLUTANTS

Thus, with the increased use of fossil fuels, the polluted urban environment has accelerated the process of weathering of stone surface many times that of natural environs. Among the important agents of stone-decay are the aggressive atmospheric impurities such as SO_2 , SO_3, NO_2, Cl_2, CO_2, the rain-water and the biological life. Among the aerosols varying from molecules to rain-drops, those in the size range of 10^{-1}, to 10^{-3} microns predominate in the decay of stone. Depending upon the crystal lattice properties' the process of re-adjustment among minerals and rocks may be slow as a geological process, it may be sometimes rapid enough to inflict enough damage within a generation.

The decay of stone is mostly due to solvent action of water and its dissolved impurities including carbon-di-oxide, inflicting acid corrosion. Some of the pollutants that attack the stone monuments are : (Vide table-I for chemical reactions).

i) Carbon-di-oxide: It is an important component of the atmosphere with an average of 0.034% (306-320 PPM) which in cities often rises to 0.27%. Its annual rate of increase due to industry and automotive burning and biological activity is rated at 0.1% to 0.3%"

ii) Chloride: It is also an important constituent of the atmosphere. Its sources are industrial, marine and desert areas. It gets converted into hydrochloric acid which readily dissolves carbonate rocks. Metal corrosion around marine environment is very common.

iii) Nitrogen Oxides: While oxides of nitrogen are distributed throughout the atmosphere at 2 to 4 micro-grams per cubic meter, they go up to 400 mg/m^3 in industrial areas. Conversion to corrosive nitric acid occurs in photo chemical smog.

iv)Oxides of sulfur: The combustion of coal, oil and natural gas release sulfur as SO_2 into the atmosphere. Sulfur may be present upto 8% in coal 4% in crude oil and 2% in natural gas. Most cityite restrict use of low sulfur coal with about 1 ½ % total sulfur. In Industrial cities coal is used at one ton per person per year including industrial use. At 50% Relative humidity, 0.6kg. of H_2SO_4 is produced per year and it rises to 4.5 kg at 98% Relative humidity and becomes much more in fog with 100% Relative humidity SO_2 slowly Oxidises to SO_3 at the rate of 0.1% to 2% per hour in sun-light, but it becomes faster in the presence of catalysts like Relative humidity, hydrocarbons and metals. SO_3 is further oxidized to sulfuric acid. Further reactions produce sulfates. Sometimes sulfates and chlorides from desert and marine areas cause serious problems.

ANOTHER CAUSE-ACID RAIN

Wash-out by precipitation is the most important process by which these air pollutants are removed from the environment. The removal of SO_2 and other gases also occurs through a process called Rain-out and wash-out. "Rain-out" consists of all processes within the clouds that cause removal of pollutants while "wash-out" refers to scavenging by precipitation below the clouds. These processes are reported to cause removal of sulfate in Frankfurt by 20% and 70% respectively. The SO_2 levels below the clouds are the same as those of the urban environment and hence very many times higher than SO_2 background levels. In areas with high carbonic , nitric and sulfuric acid in the air, rain may become very acidic in nature and consequently extremely corrosive to both stone and metals.

In fact acid-rains with pH values between 2 and 5 are reported in industrial belts of North-Eastern US, Canada N.W., Europe, Japan and India. Even in Europe precipitation acidity has been increasing for the last two decades, with H^+ concentration of rain in some parts of Scandinavia increasing more than 200-fold since 1956. Enormous quantities of oxides of Nitrogen are produced in the combustion of Natural Gas, fuel oils and Petrol. Increasing the stack heights and installation of particle precipitators in industrial belts have only transformed the local "Soot problems" the "regional acid-rain problems". Such acid rains have acidified the lakes, killed fishes, ruined eco-systems and corroded the monuments (6).

EVIRONMNETAL DETERIORATION

It is said that under corrosive atmosphere the weathering rates of Ferrous-ferric silicate minerals approach the corrosion rates of iron. Since conducting minerals are similar to metals, they are also subject to electro-chemical attack. Thus stone corrosion can be more or less similar to metal corrosion under different environmental conditions. For the construction of the Taj Mahal several iron bars and also dowels had been used for attaching the marble stones to the structural frame work and also to fasten several adjoining blocks to each other. Such bars near the surface of the structure gradually deteriorated by rusting, producing hydrous iron-oxides. Consequently the increased volume attending change of iron into hydrous oxides had mechanically disrupted the stones. Such stones are usually replaced in time to rust disfigurement of the surface of the structure. The following equation shows how the pollutants like SO_2 cause damage by rusting.

$$4Fe + 4H_2SO_4 + 2O_2 \qquad 4FeSO_4 + 4H_2O$$

$$4FeSO_4 + O_2 + 6H_2O \qquad 4FeO.OH + 4H_2SO_4$$

The increase out-put of pollutants has accelerated the destruction of stone monuments many times since the beginning of industrial revolution. The rates of decay have been too high in certain polluted areas during the last 50 to 100 years. Now let us examine how pollutants play havoc with lime, marble and sand stones used in historical monuments.

DAMAGE OF STONES

The effects of air-pollutants on weathering of stones depend in a large measure on their structure and chemical composition. For instance, sand stone is sand cemented into a kind of rock. Quartz ($Si O_2$) Calcite, dolomite and haematite are among the minerals which act as the cementing agent. Lime-stone and marble contain essentially calcium carbonate in the form of calcite. In some sand-stones, the sand grains are bonded together by calcite.

The sulfuric acid resulting from the sulfur-di-oxide in the polluted atmosphere reacts with calcium carbonate in the sand-stone and forms calcium sulfate. So also, the sulphurious acid resulting from dissolution of sulfur-di-oxide in water reacts with the calcium carbonate in sand-stone and forms calcium sulfite which in turn is oxidized by the oxygen in the air to calcium sulfate. Similarly magnesium Carbonate reacts with sulphuric acid to form magnesium sulphate. Small quantities of CO_2 in water raise the solubility of calcium carbonate. Since the solubility of calcium sulphate and magnesium sulphate is more than 100 times as great as that of calcium carbonate and magnesium carbonate, it is significant from point of the disintegration of sand stone (7).

In case of lime and sand-stones which are not exposed to rain, thin and fairly hard layers of mostly carbonates and sulphates of calcium and magnesium form on the surfaces. Such layers do not form when stones are exposed to rain as the sulphate deposits will then be dissolved in rain water and get washed away. Such leaching out causes in flaking off of the grains. Further when gypsum is formed, the surface is slowly broken up and large pieces of sand-stone may flake off as the volume of calcium sulphate is 2.1 times as great as that of the corresponding quantity by weight of calcium carbonate. The corresponding volumetric ratio for magnesium compounds is 5.3. The thermal expansion of calcium sulphate is 5 times that of calcium carbonate.

The effects of disfigurement by soot deposition on lime stone and marble are different from those on the more insoluble surfaces of granite and sand-stone. Marble surfaces exposed to rain get eroded to some extent even in normal environment as calcite is appreciably soluble in water carrying carbon-di-oxide in solution in the atmosphere. Sometimes in highly polluted atmosphere the erosion proceeds far enough to obliterate the details of canvings and present a strong contrast with the cleaner conditions of the more exposed surfaces. Since Gramites, Sand-stones, concrete and brick are not appreciable soluble in rain water, they do not show the contrast of a marble structure but tend to become blackened all over in smoke polluted atmosphere.

Calcareous roofing slates which last for centuries in countryside are reported to require replacement with in 40-50 years under polluted urban environment. Contamination with soluble salts is another cause of stone decay as can be seen in the case of buildings near the sea.

CAUSES OF STONE DAMAGE

Even the Micro-organisms, plant animal populations can attack stone to a considerable extent both by mechanical and chemical action. The biological degradation of carbonate rocks produces some gypsum from notification by Nitrogen-fixing bacteria. Sulfur-bacteria oxidize sulphur by providing an acid oxidizing solution effective in stone decay. Bacteria can break up silicate minerals along with fungi. Calcite bacteria, Arthrobacter, on lime stone surfaces actively participate in the deterioration of carbonate rocks. Actinomycetes and fungi attack silicate minerals and others by the production of carbonic, nitric, sulfuric and other weak acids. While some lichens live on silicate rocks other prefer carbonate rocks, maintain moisture and damage stone by bio-chemical chelation. Weathered rock may be populated by about a million bacteria per grown of cosk, hundreds and thousands of fungi. A summary of Microbial life and its impact on stone is presented in table –IV. Bird droppings on buildings release acids and corrode stone by bio-chemical reactions. Some forms of animal life and plant roots also cause some damage to monuments. Although the damage to stone from air pollutants is far higher than that from these biological agents, we can not afford to neglect their effects particularly in case of the magnificient and yet the most vulnerable monument like Taj Mahal.

TAJ MAHAL PRESENT SCENARIO

In order to establish the present status of preservation the monuments in Agra, the TECHNECO experts of Italy, at the request of the Indian Corporation, collected stone and dust samples from Taj Mahal, Agra Fort and Akbar Tomb. These monuments basically contain the white marble of Makrana and the red sand stone from Tantpur and Bharatpur quarries. During their inspections, the following alterations were observed.

i). For Marble:

a) Abundant deposits of yellow dust on the stone surfaces inaccessible to rain.

b) A thin black layer or small black spots on projections on the North side, near the floor as well as upper parts exposed to rain.

c) Some cracks on the slabs along the grayish veins from where visible algae growth is penetrating inside

ii). For sand-stone:

a) A heavy exfoliation of stone along the sedimentation planes.

b) A white efflorescence is present on the detaching layers in some places.

c) Large and black entrusted layers cover the surfaces in some places.

d) Insects and weeds are present in some places.

Some pieces of marble and sand stone detached from the three monuments as supplied by the Archaeological Survey were analysed and compared with the corresponding quarry stones. The results of the physical, chemical and biological laboratory analyses indicate that:

i) <u>On Marble:</u>

a) Based the soluble salts in marble, the attack at Agra Fort is higher than that at Taj Mahal

b) Low presence of soluble salts indicates that major cause of alteration is biological.

c) Among the soluble salts found, percentage of sulphates and chlorides were large.

d) Accumulation of gypsum on interior surfaces presents danger for good conservation.

e) Presence of soluble salts in dust samples collected from marble presents potential danger. Reddish grey or brown dust from marble contained not only salts but also a number of heterotrophic bacteria, actinomycetes, fungi and the auto-trophic (sulfur oxidizing and reducing ones. The origin can be attributed to the surrounding earth.

ii) <u>On sand-stone:</u>

a) Sand stone essentially consists of quartz and alkaline feldspar. Flaking is a major form of alteration.

b) On external surfaces where black patina is present, alteration is mainly due to biological action and corrosion is limited to the surface.

c) On samples with white efflorescence, decay is due to soluble salts (mostly chlorides and nitrates, the origin of which can be connected with atmospheric pollution.

PRESENT STATUS

A new Indian government survey has revealed that the Taj Mahal, the nation's best-known monument, is again facing a major threat from pollution.

The report, compiled by India's <u>National Environment Engineering Research Institute</u>, shows that measures taken after previous scares that the 17th-century tomb was being irreparably damaged by air and water pollution are failing.

The survey, commissioned by the Ministry of Environment, found that pollution levels in the city of Agra, where the Taj Mahal is located, had risen significantly over recent years as a result of growth in industry, traffic and population.

The £90m government programme, launched between 1998 and 2000 after the monument's famous white marble was seen to be turning yellow, has had some impact, the report says, but not enough to keep up with pollution around the site.

When launched, the programme received global attention, with President Bill Clinton saying that pollution had done "what 350 years of wars, invasions and natural disasters have failed to do [and] begun to mar the magnificent walls of the Taj Mahal".

Vehicles are now banned from within 500 metres of the monument and an LED display gives a running count of air pollution.

But the new report found that emissions of nitrogen oxide and particulates, for example, had reached levels higher than those that prompted a supreme court intervention to force authorities to act a decade ago.

Environmental campaigners in Agra, a bustling manufacturing centre in the populous and poor northern Indian state of Uttar Pradesh, said that the Taj Mahal was also threatened by dropping water tables and pollution from the river Yamuna, which runs alongside the structure. "The levels are much lower than they were when it was built and there is a serious risk that the whole construction will be destabilised as its foundations are made of wood and need to be kept moist to avoid subsiding," said Ashwina Kumar Mishra, a local activist. Each year hundreds of thousands of foreigners pay around £10 each to view the Taj Mahal, built by the Mughal emperor Shah Jahan as a mausoleum for his third wife, Mumtaz Mahal, who died having the couple's 14th child.

President Nicolas Sarkozy of France and his wife, Carla Bruni-Sarkozy, are due to visit next week.

DK Joshi, a member of a court-appointed committee created to monitor environmental threats to the Taj Mahal, told the Guardian that "collusion between a land mafia and dishonest bureaucrats" had meant the misuse of much of the money designated to protect the site and its surroundings

CONCLUSIONS:

From review of the various reports on the Environmental impact of Mathura Refinery it may be concluded that:

i) The approach of scientists and technologists of the Expert Committee to this problem is like that of the proverbial blind-men to the elephant.

ii)The I.M.D. and TECHNECO reports are based on many unreliable but convenient assumptions and hence their mathematical predictions using computers can not be expected to be more truthful than the reliability of the data used in the computations. For instance they have used wind data of Delhi and not that of Agra.

iii) The studies were made only for dispersion of sulfur-di-oxide and they have ignored the effects of other pollutants like Oxides of Carbon and Nitrogen, dusts and hydro-carbons and their impact and acid-rains and corrosiveness of the atmosphere upwind of Agra, so also they ignored the “Multiplier Effect” of this refinery and its down-stream units and their impact on increased levels of transportation and pollution.

iv) The expert committee even without making the Environmental Inventory, Environmental Impact Assessment and Environmental management studies of the Refinery and its subsequent growth and down-stream units over the ecologically sensitive Mathura-Agra-Fatehpur-Sikri-Bharatpur region has deliberately manipulated the scientific and technical opinion at its 6^{th} meeting on 1-5-1976 that the pollution will be within safe levels and hence there is no need to shift the site for the refinery. Thus the Ministry of Petroleum was always misled by the Governmental pseudo-experts in the Environmental field.

v) In view of the serious objections raised against the IMD and TECHNECO reports by the Director of National Environmental Engineering Research Institute, Director of Conservation of Archaeological Survey of India, President of Bombay Natural History Society and Dr.T.Torraca, UNESCO Expert and Director of Conservation, Rome, it is essential to publish these reports and organize a Public debate on the issue so that Government can take a proper decision on shifting the Refinery, if needed to a less risky site to avoid making Taj Mahal as the first Guinea-pig to study impact of pollution on marble works.

vi) As the Yamuna Waters receive the treated effluents from the refinery, Agra water supply will cause health hazards, leading, perhaps, to a forced closure of the refinery at a future date.

Taj Mahal will slowly deteriorate in the same way as Acropolis, Venice and Cleopatra' Needles. Ultimately the Nation may be forced either to abandon the Taj Mahal that earns crores of foreign exchange or the refinery on which Rs.300 crores would have been spent by that time. Let us remember that prevention is always better than cure even in case of Environmental problems and conservation of cultural property that we hold in trust for all mankind.

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