

# Importance, Novelty and Formulation of Indian Weathering Cycle

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## Abstract

Weathering is the adverse response of a material or product to climate, often causing unwanted and premature product failure. The factors responsible for weathering are; solar radiation (light energy), temperature and water (moisture). The specifications of weathering cycles in Indian standards refereed from European regulations, American standards or Japanese standards; hence the entire weathering specifications based on the respective countries data. These specifications may not be suitable for Indian weathering climate as well as usage requirements. Any material design should permit the independent selection of the major degrading forces such as UV radiation, temperature, humidity, and rain. Thus the selection of the right combination for a particular location and time of year should be easy and should give a cycle that truly simulates natural conditions. Hence, deriving the data for the standards as per Indian requirements is of prime importance. In this context, collected the Indian climatic data from five different regions considering India is one of the largest geographical areas and standardize India specific weathering test specification/ cycle.

Daily solar radiation (light energy), temperature, humidity and rainfall data collected from metrology department of different regions of India for the period 5 years are used to study the climatology and spatial and temporal characteristics of Indian weathering variations. Comparison of the Indian wreathing data with the Global weathering cycle shows a variation in each parameters. The India specific weathering data collected during the course of this study will prove to be of significant importance to automobile manufacturers, testing agency and useful in development of Indian weathering standards. Also India specific weathering study of polymers helps Indian automobile manufacturer for selection of polymers as per Indian conditions.

**Keywords:** Weathering, Solar radiation, Temperature, Humidity, Weathering cycle, Polymers degradation

## Introduction

Products which are exposed to a variety of climatic conditions must be studied initially to determine the influences of different weathering conditions. Weathering is the adverse response of a material or product to climate, often causing unwanted and premature product failure.

The factors responsible for weathering are; solar radiation (light energy), temperature and water (moisture). Solar irradiance on materials causes fading, color change, surface erosion, loss of gloss etc. Temperature's effect on material weathering includes thermal oxidation degradations, and accelerating of other weathering reactions. The influence of moisture on materials causes expansion and stresses that

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result in peeling, cracking, stress fractures and flaking etc. These factors in conjunction with secondary effects such as airborne pollutants, biological phenomena and acid rain, act together to cause “weathering”. However, the major challenge is to predict long term behavior from short term laboratory or field exposures[1, 2].

Literature available in this field is very much scarce. The literature survey gives briefs on various types of plastic materials used in different applications and, their characteristic, martial composition, usage and limited information on changes of properties due to weathering. It also gives a brief in-sight into technical papers and various studies conducted by different authors / Institutions in the field of weathering on plastic materials, paints etc.

Vishnu Shah explains that environmental factors have significant detrimental effects on appearance and properties. He identified factors of weathering such as solar radiations, microorganisms, bacteria, fungus, mold, high humidity, Ozone, oxygen, water, thermal energy, pollution and its properties which will affect on the plastics. Different techniques of weathering testing used to evaluate degradation of plastics due to weathering are discussed. Finally he has concluded generically effect of these factors on plastics [3].

Weathering Testing Guidebook by Atlas Material Testing Solutions[1], explains the Factors responsible for weathering which includes what is weathering, factors of weathering, secondary effects, synergy, climate, measuring factors of weathering etc.,. It also explains the types of weathering test such as Natural testing and Laboratory testing, procedure, evaluation etc. Which also explains the weathering cycles simulates the different weathering conditions of natural weathering and their standards. This helps to researches to select the type of testing, cycles required for simulation etc.

George Wypychwork provides comprehensive and current information on material weathering including brief information on effect of weathering on for over forty families of polymers[2, 3, 4, 5, 6].

Studied different National / International standards requirements used for evaluation of different types of automotive components under weathering effects for vehicle certification purpose [7-14].

Different SAE and ISO standards specify the test procedure of weathering for different polymers, textiles, colour, painting etc. These standards also specify the indoor and outdoor weathering, equipments, light sources etc. along with evaluation procedure and requirements[15-22].

## Weathering

Weather in a particular geographic location has a unique set of conditions which are difficult to reproduce exactly in any research setup. The exact weather data for a given geographic location are very important to relate weathering rates of laboratory equipment to the actual weathering rates. Providing the data requires separate treatment and a different medium (database or software).

In this journal these weather fundamentals are addressed:

- The general relationships between geographic locations and magnitudes of basic parameters of weathering
- Selected weather data for some reference locations
- Selected weather data for moderate and extreme conditions where products are most frequently used or may be used, respectively.

Although many weather parameters work in combination we may evaluate them in a fundamental way only one parameter at a time. Such information is very useful in planning weathering studies and interpreting their results. It is not practical to determine the weathering characteristics of materials in all of the world’s climates. Therefore, benchmark climates selected for exposure testing are based on their known severity for the weathering of materials and the anticipated market of the product to that country. The major marketing area of the material should be taken into consideration when selecting suitable climates and sites for weathering tests of that country.

How close we are to this dream? Certainly, the duplication of selected weather conditions in a single test is not impossible. Laboratory instruments are designed (or at least they should be) to simulate outdoor conditions as closely as the current technology permits. Such a design should permit the independent selection of the major degrading forces such as UV radiation, temperature, humidity, and rain. Thus the selection of the right combination for a particular location and time of year should be easy and should give a cycle that truly simulates natural conditions.

There are three problems which require solution:

- weather variability
- which part of the year should be simulated
- which climatic conditions are to be selected for products used worldwide.

These issues raise serious complications in testing. Natural weather variability is the simplest to deal with. This is routinely done by weathering services which base their typical conditions for a location on averages of test results collected over many year[2].

Over 480 standards have been issued by the European Standardization Committee (CEN), the International Commission on Illumination (CIE), the German Standards Organization (DIN), the International Standardization Organization (ISO), the Association of German Automotive Manufacturers (VDA), and the Association of German Engineers (VDI) which are directly relevant to weathering and their conditions. In North America, over 110 similarly relevant standards have been issued by the American Association of Textile Colorists and Chemists (AATCC), the American Society for Testing and Materials, and the Society of Automotive Engineers (SAE). These standards have been tailored to fit requirements of weathering studies in the United States of America. More than 130 standards have also been issued by various corporations (mainly automotive companies). These standards are relevant in assessment of weathering properties of their products. Many other national and international organizations have also issued standards on material weathering[2].

These standards include information on material weathering that may be classified as follows:

- General procedures, standard practices, terminology, and reference materials
- practice of operation of various instruments, including open flame carbon arc, enclosed carbon arc, fluorescent light, and xenon arc
- Material or industry specific standards
- Product specific standards or recommendations regarding weathering.

As a first time daily solar radiation (light energy), temperature, humidity and rainfall data collected from metrology department of different regions of India for the period 5 years are used to study the climatology and spatial and temporal characteristics of Indian weathering variations. The purposes of this work are to study the solar radiation (light energy), temperature, humidity and rainfall climatology and to examine the temporal and spatial characteristics of these parameters over India. Even though data collection includes daily, monthly, yearly data, for the purpose of compressing the data, reported only five year average data, comparison of all five region of India and comparison with the international data.

## Data Collection

There is no Indian weathering data available to conduct the study / test on polymers, hence it was decided to collect data for total Solar Radiation ( $\text{MJ}/\text{m}^2$ ), Ambient Temperature ( $^{\circ}\text{C}$ ), Relative Humidity (%). In view of large area of India and anticipated variations in climatic conditions, the data was collected at five cities namely; Pune, Delhi, Kolkata, Nagpur,

Chennai representing Western, Northern, Eastern, central and southern respectively. Five year daily raw data was procured from the respective Meteorology departments and applied statistical tool to make a standard cycle for Indian weathering.

## Total Solar Radiation

Total (or global), diffuse and direct radiation measurements have been collected by meteorological stations for several decades. There are several important measurement of different types of radiation which includes;

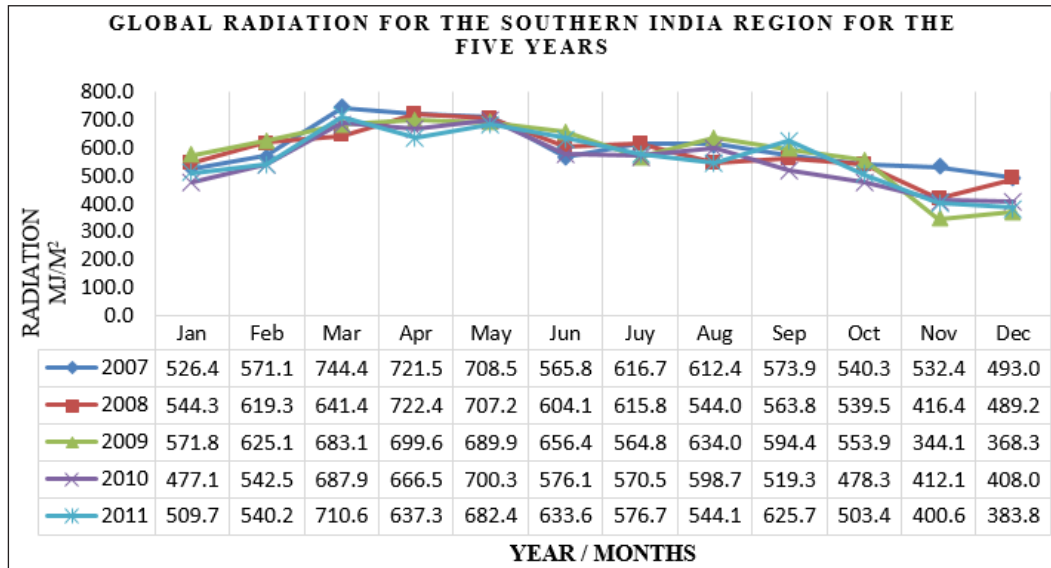
- Global Solar Radiation is the total incoming shortwave (usually  $<3000\text{ nm}$ ) solar radiation coming from the entire dome of the sky as received on a flat, horizontally-mounted thermopile surface.
- Sky Radiation is that portion of the total incoming radiation received on a flat, horizontally-mounted thermopile surface which is shielded from the direct rays of the sun by a shade ring.
- Reflected Radiation is that portion of the total radiation which has been reflected from the Earth's surface and received on a flat, horizontally-mounted, downward-faced thermopile surface.
- Net Radiation is the net difference between incoming and outgoing radiation.

For the purpose of computation of weathering cycle, only total global solar radiation ( $\text{MJ}/\text{m}^2$ ) (usually  $<3000\text{ nm}$ ) was procured for 5 years data and same will be statistically derived.

The Tables 1 to 5 shows the total global solar radiation ( $\text{MJ}/\text{m}^2$ ) data of India-Chennai (southern region), India-Delhi (Northern region), India-Kolkata (Eastern region), India-Pune (Western region) and India- Nagpur (central region) respectively. These tables also represents the total radiation of monthly for the five years for all the above referred regions. These data was derived from adding each day of total radiation for respective month. Table 6 shows the total global solar radiation ( $\text{MJ}/\text{m}^2$ ) data of all India.

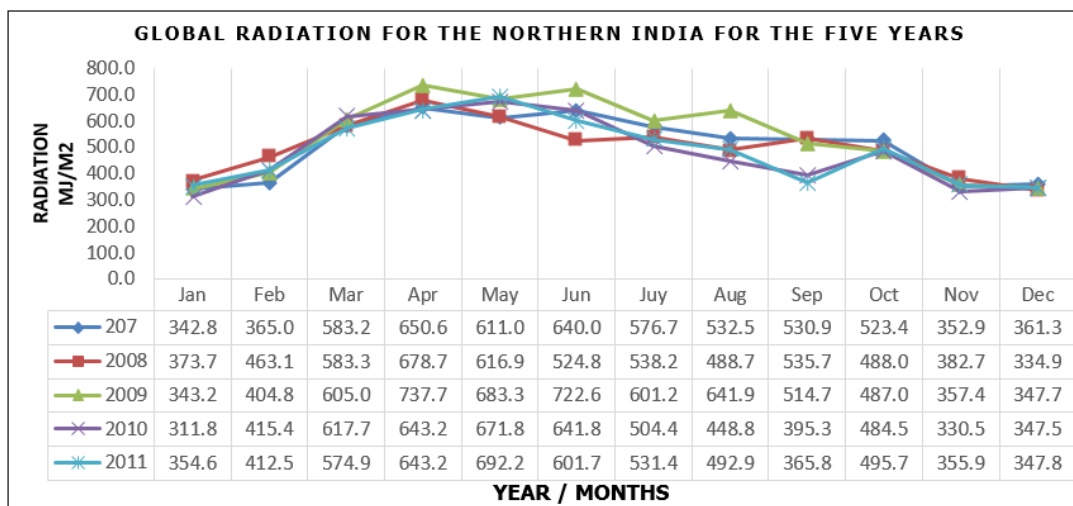
Table 1 compares the total solar radiation of India-Chennai (southern region) data. In this region gets more radiation in the month of March-May and less in the month of November-December, however there is not much difference in the rest of the months of the respective years.

Table 2 compares the total solar radiation of India-Delhi (Northern region) data. In this region gets more radiation in the month of April –May-June and less in the month of November-December-January, however there is not much difference in the rest of the months of the respective years.



**Table 1. Global radiation for the Southern India region for the five years**

Total Global Radiation for 5 years for Southern India	34584.4
Ave. global radiation for 5 years for Southern India	6916.9



**Table 2. Global radiation for the Northern region for the five years**

Total Global Radiation for 5 years for Northern India	30206.4
Ave. global radiation for 5 years for Northern India	6041.3

Table 3 compares the total solar radiation of India-Kolkata (Eastern region) data. In this region gets more radiation in the month of April –May–November – December and almost same amount in all these months. However there is not much difference in the rest of the months of the respective years.

Table 4 compares the total solar radiation of India-Pune (Western region) data. In this region gets more radiation in the month of May and less in the month of November–December–January. Generally the radiations gradually start increasing from February till May and decreases in June

and stable will be upto October. The figure also shows that in the month of October always slight increase.

Table 5 compares the total solar radiation of India-Nagpur (Central region) data. In this region gets more radiation in the month of May and less in the month of December–January. Generally the radiations gradually start increasing from March till May and decreases in June and stable will be upto October. The figure also shows that in the month of October always increase. However there is not much difference in the rest of the months of the respective years.

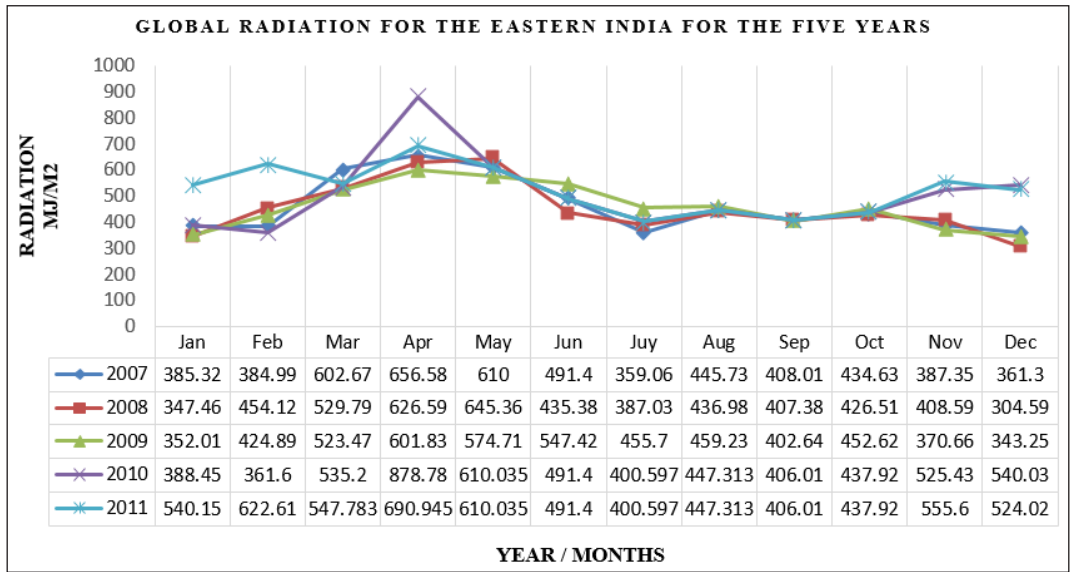


Table 3.Global radiation for the Eastern India for the five years

Global radiation for the Eastern India for the five years	28742.4
Ave. global radiation for 5 years for Eastern India	5748.5

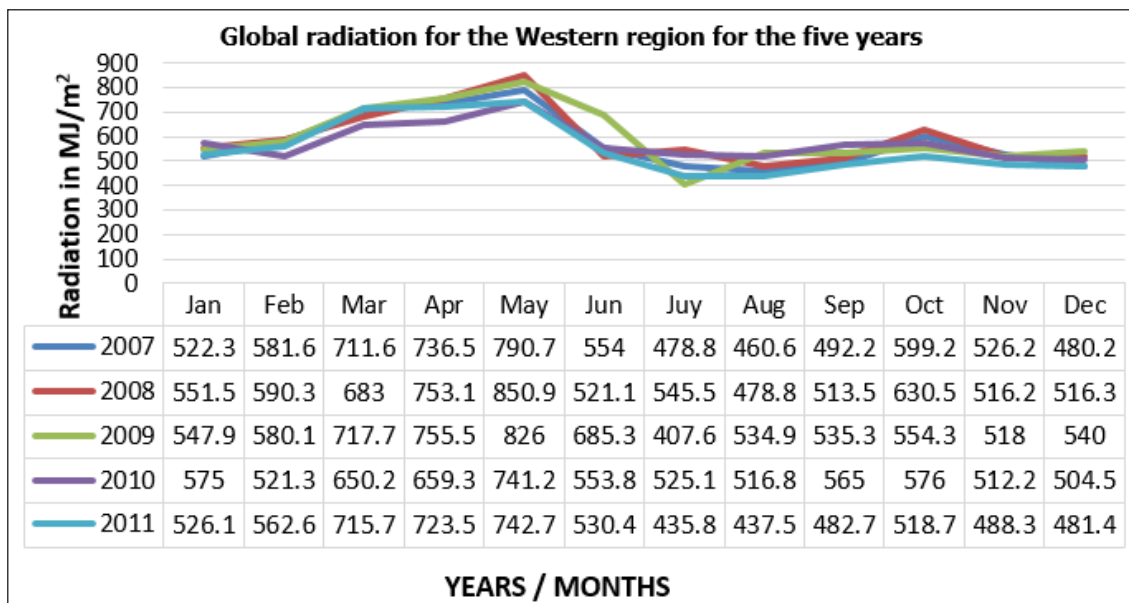


Table 4.Global radiation for the Western region for the five years

Total Global Radiation for 5 years for western India	34832
Ave. global radiation for 5 years for western India	6966

Table 6 shows the total global solar radiation (MJ/m<sup>2</sup>) data of all India. The comparison shows that Southern India gets more global radiation followed by western region and eastern region India gets lesser radiations followed by Northern region. Central region gets average of all India data. Generally in Northern India gets maximum radiation in the month of May – June however it is reverse cycle in the month of December-January compared to all India.

Table 7 shows the comparison of total global solar radiation (MJ/m<sup>2</sup>) data of all India versus Miami-Florida, Phoenix-Arizona, SanarysurMer, France, Hoek van Holland and The Netherlands. The comparison shows that, average all India global radiations very close to the Miami-Florida and SanarysurMer, France. However observed major variation compared to all other countries data.



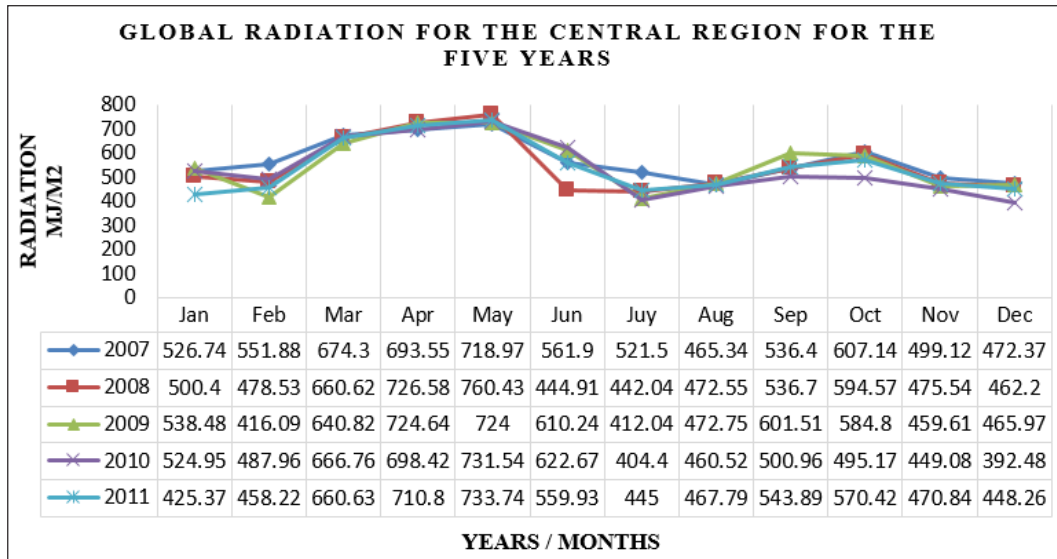
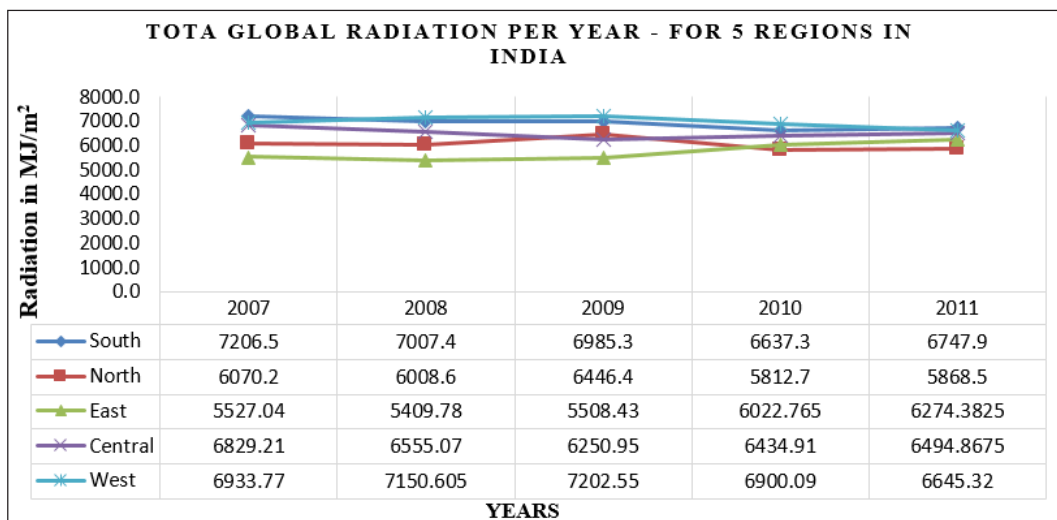


Table 5.Global radiation for the central India for the five years

Total Global Radiation for 5 years for central India	32565.0
Ave. global radiation for 5 years for Central India	6513.0

Table 6.Shows the total global solar radiation (MJ/m<sup>2</sup>) data of all India

## Temperature

Temperature's effect on material weathering includes thermal oxidation degradations, and accelerating of other weathering reactions. "Rule of Thumb" is that 10°C increase in temperature doubles Rate of chemical reaction. Also solar radiation plus high temperature equals increased Rate of Degradation.

There is a substantial difference between temperatures reported by meteorological stations and temperatures recorded in weathering investigations. However temperature measurement in World Meteorological Organization (WMO) stations is in all probability the most precise measurement. In meteorological stations, air temperature is recorded

with an instrument that is not exposed to or affected by radiation. Air does not absorb a lot of heat energy from infrared radiation thus the temperature measurements are lower than the temperature developed on a solid surface exposed to sun. Three types of measurements are performed: minimum temperature, maximum temperature and average temperature, all in specified time intervals. Like solar radiation data reported above, temperature and humidity is not reported in details even though all the data was available. However the average, maximum and minimum temperature compiled using each day data collected.

Table 8 shows the comparison of maximum temperature of all India versus Miami-Florida, Phoenix-Arizona, SanarysurMer,

**Table 7. Comparison of total Global radiation of all India versus Miami, Florida, Phoenix, Arizona, SanarysurMer, France, Hoek van Holland and The Netherlands.**

Comparison of Global radiation MJ/m <sup>2</sup>										
Year	South India	North India	East India	Central India	West India	Avg. India	Miami, Florida	Phoenix, Arizona	Sanarysur Mer, France	Hoek van Holland, The Netherlands
2007	7206	6070	5527	6829	6934	6513	6474	7974	6497	4129
2008	7007	6009	5410	6555	7151	6426	6310	8163	6497	4129
2009	6985	6446	5508	6251	7203	6479	6495	8111	6318	4172
2010	6637	5813	6023	6435	6900	6362	6288	7847	6293	4018
2011	6748	5868	6274	6495	6645	6406	6540	8278	6499	4267
Total for 5 years	34584	30206	28742	32565	34832	32186	32108	40373	32103	20715
Avg. for 5 years	6917	6041	5748	6513	6966	6437	6422	8075	6421	4143

France, Hoek van Holland and The Netherlands. The comparison shows that, maximum average temperature with in India is in central India region. Also the comparison shows that, average all India maximum temperature does not matches with any other available data such as the Miami-Florida and SanarysurMer, France.

Table 9 shows the comparison of minimum temperature of all India versus Miami-Florida, Phoenix-Arizona, SanarysurMer, France, Hoek van Holland and The Netherlands. The comparison shows that, minimum average temperature with in India is in western India region. Generally in the winter Northern region shows extreme coldest weather in December – February, however average statistical data shows western region is having minimum temperature. Also the comparison shows that, average all India minimum temperature does not matches with any other available data such as the Miami-Florida and SanarysurMer, France.

Table 10 shows the comparison of maximum humidity of all India versus Miami-Florida, Phoenix-Arizona, SanarysurMer, France, Hoek van Holland and The Netherlands. The comparison shows that, maximum average humidity with in India is in southern India region. Also the comparison shows that, average all India maximum humidity does not matches with any other available data such as the Miami-Florida and SanarysurMer, France.

Table 11 shows the comparison of maximum humidity of all India versus Miami-Florida, Phoenix-Arizona, SanarysurMer, France, Hoek van Holland and The Netherlands. The comparison shows that, minimum average humidity for the North India, Central India and West India is comparable.

Also the comparison shows that, average all India minimum humidity does not matches with any other available data such as the Miami-Florida and SanarysurMer, France.

### Derivation of India Weathering Cycle

Laboratory instruments are designed (or at least they should be) to simulate outdoor conditions as closely as the current technology permits. Such a design should permit the independent selection of the major degrading forces such as UV radiation, temperature, humidity and rain. Thus the selection of the right combination for a particular location and time of year should be easy and should give a cycle that truly simulates natural conditions.

Products which are exposed to a variety of climatic conditions (e.g., worldwide) must be studied initially to determine the influences of different climatic conditions. Depending on the product, an initial study may result in the selection of one set of the most accelerating conditions (as in the previous paragraph) or several conditions which must be separately addressed (by testing and formulation) to sustain material performance in adverse climatic conditions. (HB-CH8)

Table 12 shows the weathering cycle followed by different standards. These standards include information on material weathering that may be classified the test conditions which includes equipment used, type light source (xenon/ carbon arc/UV/fluorescent lightetc), cycle (light/dark), temperature(Black panel / chamber), humidity etc. The total Irradiance dosage (W m-2 nm-1) of the complete cycle is depending on the test requirements, type of sample,

application, agreement between the buyer and seller of the product, hence it will varies from test to test.

The operation parameters contained in the standards, listed in Table 12, usually differed from standard to standard. The conditions specified in these product specific standards vary quite widely. There is no a logical relation between the conditions of material performance and the ability to withstand environmental condition. The selection of test conditions seems to depend on the opinion of a particular standard committee on what is possible to achieve and test in existing equipment.

Generally there are three problems which require solution namely weather variability, which part of the year should be simulated and which climatic conditions are to be selected for products used worldwide. These issues raise serious complications in testing. Natural weather variability is the simplest to deal with.

To deal with above problems, derived India specific weathering cycle based on the above data. Table 13 shows three different weathering cycle derived from three basic standards generally followed in India in different applications.

Individual manufacturer may be select different parameters specific to region if required based on above data. Similar results are also available for the extreme conditions in a particular location.

## Conclusions

- In the absence of Indian weathering data to conduct the study / test polymers, five year data was collected which includes total Solar Radiation ( $\text{MJ}/\text{m}^2$ ), Ambient Temperature ( $^{\circ}\text{C}$ ), Relative Humidity (%).
- Data was collected at five cities namely; Pune, Delhi, Kolkata, Nagpur, Chennai representing Western, Northern, Eastern, central and southern respectively and applied statistical tool to make a standard cycle for Indian weathering.
- Analysed and presented the general relationships between geographic locations and magnitudes of basic parameters of weathering
- Comparison was made with international weathering data with Indian data
- Derived three India specific weathering cycle based on the five years data

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