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A Brief Survey on the Practical Applications of Sebera Equation for Predicting Permanence Index During Transfer of Cultural Heritage to Distinct Environmental Conditions

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ABSTRACT

This work provides information about the use of Sebera Equation in the calculation of permanence index of paper documents based on simulations that include relative humidity and temperature changes, being an useful tool to predict the long-term life of paper documents in libraries, museums and archives.

Keywords: Sebera Equation, Temperature, Relative Humidity, Permanence Index, Museum, Archive

I. INTRODUCTION

Arrhenius Equation (Equation 1) is widely used in the calculation of the variation of the velocity constant of a chemical reaction with temperature. It is an equation widely used to determine chemical kinetics, and also widely used to determine the energy of activation reactions.

$$k = Ae^{-E/RT} \qquad (1)$$

Where: k = Reaction constant; A = Pre-exponential constant, dependent on the área of contact, among other factors; E = Activation energy; R = Constant of perfect gases; T = Temperature.

This equation can be used to calculate the activation energy of a series of reactions, mainly chemical reactions, such as the energy of activation for the thermal destruction of a microbial cell, deterioration of foods, degradation of paper, wood. This equation can also be used according to Wilson [1] as described in a Technical Report from NISO.

According to the description contained in the NISO Technical Report, this equation can also be used to study the degradation of paper, introduced with the objective of giving technical support to librarians, personnel from archives, engineers, architects and staff involved in the conception, construction, renovation and maintenance of buildings used as storage of collections.

The present article aims to provide technical orientation about the environmental parameters that affect deterioration of paper, if these paper documents are stored in a deposit designed for this purpose. This orientation will be based on simulations of typical situations including temperature and relative humidity changes, indicating what would be the consequence in the permanence of paper, based on calculations from Sebera Equation.

In the present paper it is intended to suggested minimum and maximum values for temperature and relative humidity, with the purpose of achieving a suitable preventive conservation. However, even though the Arrhenius Equation clearly can be used for these purposes, isoperms are being preferentially used, due to its characteristic relation between temperature and relative humidity in a single mathematical expression. The basis for the development of Sebera isoperm can be found in the combination of these two parameters, producing as a result of this combination, the measurement of the Permanence, the inverse of the deterioration rate.

The limits that can be simulated with this equation depend on the particular use intended. For instance, depending on the local climate conditions, considerations about human comfort and modern technology to control environmental standards must be considered. According to the actual practice, and also according to isoperm equations, some considerations can be reached, particularly considerations on the chemical stability of a document paper, where it is widely stated that the smaller the temperature the paper is stored, the best. However, not always conditions predicted can be achieved and not all institutions present climate control available to reach desired standards. For instance, it is widely spread the for the proper storage of paper documents the use of temperature in the range of 0 to 18°C is suitable; Variations in the temperature markedly affect the degradation of paper, in comparison to a previously stated condition; The smaller the relative humidity of the air, the best for paper documents; For daily use, paper documents must be stored at 20% relative humidity; In order to prevent fungal growth, paper must be kept at 55% relative humidity. However, these figures do not constitute the goal of some institutions, and proper simulations need to be conducted in order to reach specific targets for conservation.

In reality, the options for preservation are well known, however, the lack of studies on the matter, brings some hesitation to the use of chemical procedures to reduce fungal growth or to improve climate conditions. In that matter, the use of Arrhenius Equation with its theoretical predictions about the storage conditions of paper documents can be useful to establish suitable environmental conditions. So, this is clearly an important tool for the development of preservation techniques and policies and also to develop strategies for long-term storage, and also, prediction of lifetime of documents depending on climate changes and seasonal variations.

The relatively simple Arrhenius equation can be used as a basis to correlate relative humidity and temperature values to predict stabilization levels in relation to the stability of paper documents. In that case, Sebera Equation (Equation 2) can be used [2].

This expression correlates the permanence index (P) of a material (paper, for instance) in a particular room with the permanence index predicted during transfer of this same material for another space at distinct temperature and relative humidity levels.

$$\frac{P_2}{P_1} = \left(\frac{RH_1}{RH_2}\right)\left(\frac{T_1 + 460}{T_2 + 460}\right)10^{394\Delta H\left(\frac{1}{T_2+460} - \frac{1}{T_1+460}\right)} \quad (2)$$

Where P1 = Permanence index in the present conditions; P2 = Permanence index in the estimated desired conditions; RH = Relative humidity; ΔH = Activation enthalpy; T = Temperature.

Strang e Grattan [2] revised Equation 2, taking into account the fact that the intrinsic humidity and not the relative humidity must be considered in the evaluation of permanence of an organic material. This new approach could bring more realistic information about the process of deterioration.

This new model (Equation 3), that introduces information about the cellulose and water content of the materials, that means, the intrinsic humidity) considers the concept of isotherms and can be combined with the Sebera isoperm.

$$M = \frac{M_0 KCA_w}{(1 - KA_w)(1 - KA_w + CKA_w)} \quad (3)$$

Where: M = Cellulose and water content on a dry basis; M_0 = Content of the mixture on the surface monolayer of paper; K = Status difference between the pure liquid (water) and surface layers of the paper; C = Status difference between the monolayer and surface layers of the papers; A_w = Water activity.

This expression can be easily combined with Sebera Equation, giving place to a new expression, with a high number of parameters to be solved (Equation 4).

$$\frac{P_2}{P_1} = \frac{\dfrac{M_{01}K_1C_1A_{w1}}{(1-K_1A_{w1})(1-K_1A_{w1}+C_1K_1A_{w1})}}{\dfrac{M_{02}K_2C_2A_{w2}}{(1-K_2A_{w2})(1-K_2A_{w2}+C_2K_2A_{w2})}} x \exp\frac{\varepsilon}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) \quad (4)$$

Suggestions on the use of the present system in the prediction of permanence index based on different T and RH simulations can be presented (Table 1)

TABLE 1

SIMULATIONS OF THE PRACTICAL APPLICATIONS OF SEBERA EQUATION FOR MUSEOLOGICAL USE

Simulation	**Temperature Range (^{o} C)**	**Relative Humidity Range (%)**
A	Range T_1-T_2 (Smaller range of T between Year A and Year B) e Range T_3-T_4 (Greater range of T between Year A – Year B)	RH_1-RH_2 (Average RH between Year A and Year B)
B	T_1-T_2 and T_3-T_4 (Summer)[1]	RH_1-RH_2
	T_1-T_2 and T_3-T_4 (Autumn) [1]	RH_1-RH_2
	T_1-T_2 and T_3-T_4 (Winter) [1]	RH_1-RH_2
	T_1-T_2 and T_3-T_4 (Spring) [1]	RH_1-RH_2
C	From T1 to T2 at different reference T and RH	
D	T_1-T_2 and T_3-T_4 (Summer)[1]	RH_1-RH_2
	T_1-T_2 and T_3-T_4 (Autumn) [1]	RH_1-RH_2
	T_1-T_2 and T_3-T_4 (Winter) [1]	RH_1-RH_2
	T_1-T_2 and T_3-T_4 (Spring) [1]	RH_1-RH_2
E	Similar To Simulation D, considering ΔH = 25 kcal	

[1]Reference conditions: ΔH = 35 kcal, T = 23 ^{o}C or 25 ^{o}C and RH = 60 % or 65%.

From Table 1 it can be estimated the effects of the transfer of paper documents from different climate conditions, predicted by the equation.

For example, in Simulation A, the use of the lowest or highest temperature range in a certain period, can bring useful information about the effect on the transfer of paper documents from one place to another, at distinct environmental conditions. It can also be useful to predict permanence index between hot and cold seasons. This can be predicted based on the permanence index, bringing information about what can be expected between extreme conditions all over the year.

In the case of Simulation B, the use of the equation can serve to predict climate changes due to different seasons of the year. In this case, it is important to consider minimum and maximum observed temperature and relative humidity values, in order to characterize what is expected from the permanence index, under extreme cold and hot weather conditions.

It is known that environmental conditions do not change abruptly during the transition of a season to another. It is a gradual process, being also gradual the daily changes in the permanence index, as temperature and humidity gradually change. This way, simulations that can predict the effects from growing temperatures, for instance from 30 a 40^{o}C, in comparison to pre-determined reference conditions, such as 23^{o}C/60%; 25 ^{o}C/60%; 23^{o}C/65% e 25^{o}C/65 %, typical of tropical countries are useful during changes in the cycles of temperature control in indoor spaces.

In simulation D it can be expected to know permanence index in conditions where it is possible to evaluate the effect of growing RH considering small and high T ranges between one specific year and another, or between a range of years can be easily performed based on the equation. Similar conclusions can be reached by changing ΔH value from 25 to 35 kcal, as predicted by some literature sources (Simulation E).

In fact, this brief survey includes just simulations of some climate conditions, opening the possibility of performing infinite simulations, to calculate permanence index for a wide range of T, RH and not only paper, but any other museological piece amenable to suffer from unsuitable storage conditions.

II. REFERENCES

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