



Investigation the Weather Effects on the Sound Absorption coefficients in Cinjar city

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ABSTRACT

In this work , the absorption coefficients A_a had determined for different acoustic source by the air atmosphere for one day in Cinjar city, based on an analytical method which employed on several empirical equations that taking in consideration the various meteorological conditions in which the climate elements changed in additional to frequencies sources .The results shows the atmospheric absorption is sensitive to the composition of air , particularly to the wide varying concentration of water vapor and temperature where the air temperature play and frequency variation are dominate that controlling the values of A_a .

KEYWORDS

Total Acoustic absorption coefficients; Oxygen and Nitrogen relaxation frequencies; ISO1993.



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1-INTRODUCTION

When the acoustic wave propagates, all its energy is converted into random thermal energy. The sources of this dissipation may be divided into two general categories:

those intrinsic to the medium and those associated with boundaries of the medium. Losses in the medium may be further subdivided into the basic types: viscous losses, heat conduction losses, and losses associated with internal molecular processes. Viscous losses occur whenever there is relative motion between adjacent portions of the medium, such as during compressions and expansions that accompany the transmission of a sound wave. Heat conduction losses result from conduction of thermal energy from higher temperature condensations to lower temperature rarefactions. The molecular processes leading to absorption include the conversion of kinetic energy of molecules into [1]:

(1) Stored potential energy (as the structural rearrangement of adjacent molecules in some cluster). (2) Rotational and vibrational energies (for polyatomic molecules).

In a real atmosphere, the sound propagation deviates from spherical wave diffusion due to a number of factors, including absorption of sound in air, non-uniformity of the propagation medium due to meteorological conditions (refraction and turbulence), and interaction with an absorbing ground and solid obstacles such as barriers [2].

Stokes [3] developed the first successful theory of sound absorption due to the effect of molecular viscosity of a fluid. Tyndall [4] experimentally investigated sound propagation in aerosols like fog. Rayleigh [5] estimated the scattering effect of small spherical obstacles in a non-viscous atmosphere and showed that the effect depends on the number of scattering particles and the ratio of their diameter to the wavelength of the sound. Sewell [6] studied theoretically the absorption of sound in a viscous medium containing suspended cylindrical and spherical particles (obstacles). Dennis A. Bohn [7] studied analytically the environmental effects like temperature and humidity on the acoustic absorption. Gavin R. [8] used simple algebraic formulas for calculating the linear acoustical properties of air, except the absorption coefficient, in terms of ambient temperature and pressure. Scott Penton et al [9] illustrates the meteorological effects on predicted noise levels reduction, by comparing modeling results from five calculation algorithms, including basic modeling (considering distance attenuation and barrier effects only). Dennis A. Bohn [10] expands, and clarifies the environmental effects of temperature and humidity on the speed of sound. These effects increase the speed of sound and complicate the task of room equalization immensely. The aim of this study is to determine the acoustic attenuation coefficient by atmosphere components for frequency range 50 Hz to 8000 Hz in a summer day in Tikrit city by depending on a global empirical method given by [11].

2-THE METEOROLOGICAL ELEMENTS AFFECTING THE OUTDOOR SOUND PROPAGATION

The atmosphere basically consists of a two-component system, one component is dry air and the other is water existing in vapor phase or one of the condensed phases (liquid water or ice). Table 1 shows the stable and unstable gaseous components of the atmosphere.

Table (1): Composition of atmospheric gases [12].

Constant configuration (Values stable over time and place)	
Nitrogen (N ₂)	78.08 %
Oxygen (O ₂)	20.95 %
Argon (Ar)	0.93 %
Neon, helium, krypton	0.0001 %
Variable configuration (Values unstable over time and place)	
Carbon dioxide (CO ₂)	0.039 %
Water vapor (H ₂ O)	0 to 4 %
Methane (CH ₄)	traces
Sulfur dioxide (SO ₂)	traces



Ozone (O ₃)	traces
Nitrogen oxides (NO, NO ₂)	traces

In this model, we use only two major components of atmosphere gases like Nitrogen and Oxygen which is compromise about 90% of air . The next section ,we review all the atmospheric parameters that affect sound propagation and as follow .

2-1 HUMIDITY (H) DEPENDENCE

It is important to know the saturation condition of air i.e. how far its removed from its saturation limit .In other words, the important factor is not the actual amount of water vapor present in air but its closeness to the saturation value .The degree of saturation of the air determines its Relative Humidity H and defined by [14]:

$$H = \left(\frac{\text{density of water vapour present in air}}{\text{density of saturated air at the same temperature}} \right) 100\% \dots\dots\dots(1)$$

Since both volumes are equal , the above equation can reduce to in the form

$$H = \left(\frac{m}{M} \right) 100\% \dots\dots\dots(2)$$

Where *m* is the mass of water vapor present in the air and *M* is the mass of saturated atmospheric air and here H is a dimensionless quantity.

2-2 FREQUENCY DEPENDENCE

The frequency (*f*), which is the number of pressure variation cycles in the medium per unit time, or simply, the number of cycles per second, and is expressed in Hertz (Hz). Audible range is usually composed of many frequencies(20Hz-20KHz) combined together[15]

2-3 PRESSURE DEPENDENCE

Atmospheric pressure, also called barometric pressure, force per unit area exerted by an atmospheric column (that is, the source of air above the specified area). Atmospheric pressure can be measured with a mercury barometer (hence the commonly used synonym *barometric pressure*), which indicates the height of a column of mercury that exactly balances the weight of the column of atmosphere over the barometer[15]. As a pure tone sound propagate through atmosphere over a distance *r*, the sound pressure amplitude *p_T* decreases exponentially [11].

$$p_T = p_i \exp(-0.1151\alpha r) \dots\dots\dots(3)$$

Where *p_i* is the initial value of the pressure and *α* is the attenuation coefficient of sound for frequency and meteorological state .

2-4 TEMPRATUR DEPENDENCE

When a gas (here air) is heated at constant pressure , its volume increases and its density is decreased ,because of this decrease in density , velocity increased with the rise in air temperature [16]:

$$v_T = 331.3m / \text{sec} \sqrt{1 + \frac{T}{273.15^0 C}} \dots\dots\dots(4)$$

Where 331.3 m/sec is the speed of sound in air at 0 °C and T is the temperature of air in degree Celsius. Hence the increase in velocity for an increment of 1 °C is 0.61 m/sec . We note the percentages of gases from table 1 that diatomic molecules and carbon dioxide each have two degree of rotational freedom , fully excited at room temperature .Water vapor has three rotational degrees ,but due to its low concentration (even at high relative humidity) contributes only slightly to the rotational component of specific volume heat capacity of air [1].

3-THEORETICAL BASIS

To certain degree ,everything absorbs sound ,especially air , wet air absorbs sound better than dry air .The predominant mechanism of absorption (the classical and rotational relaxation) proportional to the square of frequency. The vibration relaxation effect depends on the relaxation frequencies of the gas constituents (O₂ 20.96% and N₂ 78.03%) and is highly dependent on the relative humidity[2]. The mechanism for acoustic attenuation can be predicted by account



the internal structure of the air molecules and interactions between them that lead to internal vibrations ,rotations and short-range ordering . The oldest and most successful of many approaches to this problem is that treating molecular thermal relaxation in gases composed of polyatomic molecules .In the thermal relaxation theory it is acknowledged that in addition to the three degrees of translational freedom each molecule possess , there are also internal degrees of freedom associated with rotation and vibration .The time necessary for energy to be transferred from translational motion of the molecule into internal states compared to the period of the acoustic process determines how much acoustic energy will converted to thermal energy during the transitions. If the period of the acoustic excitation is long compared to the relaxation time τ of the internal energy state ($\omega\tau \ll 1$), then the state can be fully populated ; the phase lag is finite but small , so the fraction of energy lost is very small , so the fraction of energy lost is very small over each period of the motion [17] .On the other hand ,if the acoustic period is much shorter than the before condition ($\omega\tau \gg 1$), the internal energy state cannot be heavily populated before conditions are reversed , and the energy loss over each period will also be small [1].The related equation for computing A_α is given by [11]:

$$\alpha = 8.69 \times f^2 [1.84 \times 10^{-11} \left(\frac{p_a}{p_r}\right)^{-1} \left(\frac{T}{T_0}\right)^{\frac{1}{2}} + \left(\frac{T}{T_0}\right)^{-\frac{5}{2}} [0.01275 \frac{e^{\frac{22391}{T}}}{f_{r,O} + f^2 / f_{r,O}} + 0.1068 \frac{e^{\frac{3352}{T}}}{f_{r,N} + f^2 / f_{r,N}}] \dots\dots\dots(5)$$

Where $f_{r,O}$ and $f_{r,N}$ are the oxygen and Nitrogen relaxation frequencies which are defined as below :

$$f_{r,O} = \left(\frac{p_a}{p_r}\right) [24 + 4.04 \times 10^4 H \frac{0.02 + H}{0.391 + H}] Hz \dots\dots\dots(6)$$

And the Nitrogen relaxation frequency is given by

$$f_{r,N} = \left(\frac{1}{p_r}\right) \left(\frac{T}{T_0}\right)^{-\frac{1}{2}} \left(9 + 280H \exp(-4.17 \{ (\frac{T}{T_0})^{-\frac{1}{3}} - 1 \}) \right) Hz \dots\dots\dots(7)$$

Where α is the distance –independent a coefficient absorption and equations 6 and 7 the symbol H is the molar concentration of water vapor (absolute humidity) in percent is calculated from the relative humidity H_r as follows:

$$H = p_r \left(\frac{H_r}{p_a}\right) \left(\frac{p_{sat}}{p_r}\right) \% \dots\dots\dots(8)$$

Where the saturated vapor pressure p_{sat} is given by :

$$p_{sat} = p_r \times 10^{\left[-6.8346 \left(\frac{T_{01}}{T}\right)^{1.261} + 4.6151 \right]} \dots\dots\dots(9)$$

The symbols are defined as :

- T_0 = reference temperature 293.15 K (20°C).
- T = ambient atmosphere temperature in Kelvin scale .
- T_{01} = 273.16K
- p_r = reference ambient atmosphere pressure =101.325kPa.
- p_a = ambient atmosphere pressure in pas.
- H = Relative Humidity .
- f = frequency source

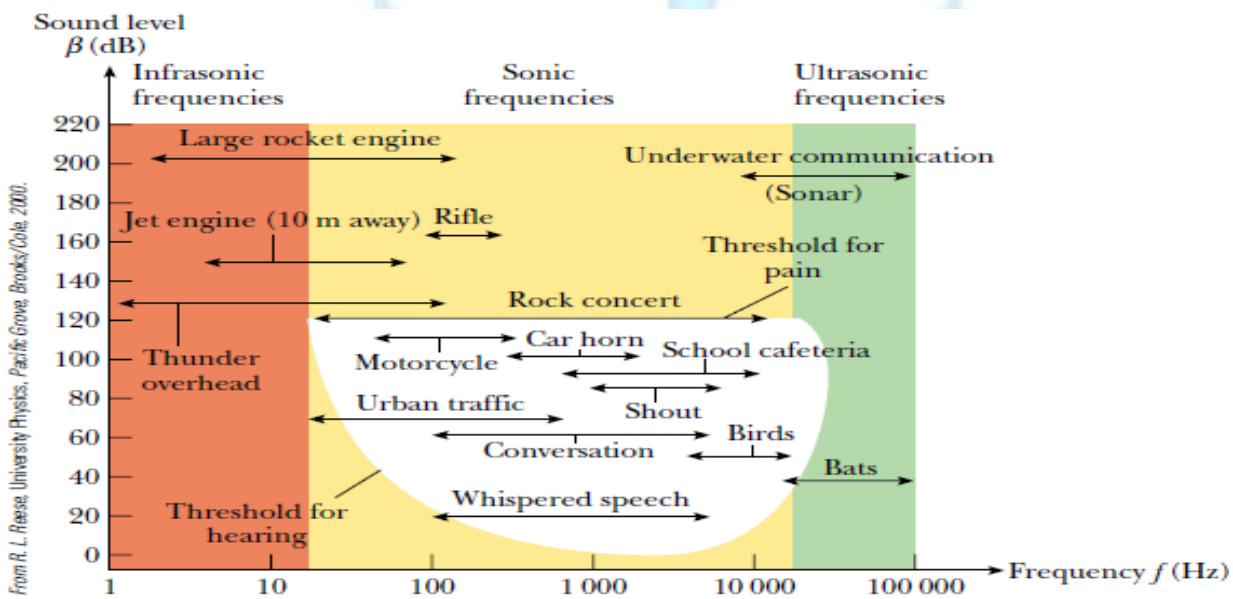
The total absorption A_a measured in decibels due to atmosphere absorption at a distance r in the level of a pure tone with frequency f at the initial level at $r=0$ to level at range of r , is given by [11] :

$$A_a = \alpha r / 1000 \text{ dB/Km} \dots \dots \dots (10)$$

Where in this calculations, we presumed the absorption distance equals to $r=1000\text{m}$ and the frequencies used throughout this study are less than 10KHz.

4-RESULTS AND DISCUSSION

All the meteorological data employed throughout this work has been taken from [18] for one day 8/8/2013 in Cinjar city and the frequencies ranges are used here taken from figure 1 [16].As known the atmospheric attenuation is sensitive to the composition of air , particularly to the wide varying concentration of water vapor .By checking the results given in the table 3, we note that as sound source frequencies are increased the acoustic attenuation coefficient According to the equations (5) and (10). By comparison the obtained results of attenuation coefficients, in the first two column, we found that these coefficients decreased with increasing the relative humidity and this behavior satisfying the equations(6) and (7) which are influence directly on the relaxation frequencies of both nitrogen and oxygen(increasing the relaxation frequencies)and in turn the attenuation coefficient will increases and this behavior applied for all data in the same table.



Fig(1): Approximate frequency and sound level ranges of various sources and that of normal human hearing, shown by the white area.

It is interesting to note that the absorption increases rapidly with temperature ,water vapor appears to act as a catalyst , increasing the relaxation frequencies associated with vibrational states of N_2 and O_2 , in other words, from the table 3, we note that the A_a increases with increasing temperature in all the meteorological conditions which , reflects the fact that the temperature play an important role in variation of A_a .Oxygen and water vapor collisions exciting the O_2 vibrational states and assume greatest importance for absorption at frequencies between about 100Hz to 1KHz . In a very dry air the collisions with water vapor become unimportant , and collisions of N_2 with CO_2 become important and since the moist air is lighter than dry air , the velocity of sound is greater in moist air than in dry air . Moisture also causes the specific-heat ratio to decrease, which would cause the speed of sound to decrease. However, the decrease in density dominates, so the speed of sound increases with increasing moisture. We note as frequency increases the attenuation coefficient increases while the relation is inversely with temperature , humidity and pressure respectively . Finally All the model equations employed here [11] are applicable only for steady meteorological conditions and frequency less than 10KHz , in other words this formulas are applicable only in clear day ,when there are no fog, storms , hurricanes and rain because the model equations are not included specific parameter related to metrological factors mentioned above .



5-CONCLSIONS

- Atmospheric absorption of sound is important for outdoor sound propagation. Weather changes over the day and the year, and this alters the atmospheric absorption. The size of the daily variances was frequency-dependent.
- The most accurate information about atmospheric absorption climate is achieved if the study continuous for long time to include all
- The most powerful parameters that influences the fluctuations of A_{α} is that the air temperature with frequency-dependent to all sources.

6-REFERENCES

- [1] Lawrence E. Kinsler, Austin R. Frey, Alan B. Copen's and James V. Sanders "Fundamentals of Acoustic" 4th edition, Chapter.8, p.p210-226, John-Wiley and sons, INC (2005) USA.
- [2] Anastasias A. Tsonis "An Introduction to Atmospheric Thermodynamics" 2nd edition, Chapter 7, p.p99, Cambridge University Press, The Edinburgh Building, Cambridge CB2 8RU, (2007) UK.
- [3] G.G. Stokes "On the theories of internal friction of fluids in motion", Translated by Cambridge Phil. Soc Vol.8 p.p287-305(1845).UK
- [4] J. Tyndall "The science of sound" Philosophical Library, INC., 3rd edition New York (1964)USA.
- [5] Lord Rayleigh "The theory of sound" Vol.2, Dover New York, (1945),USA.
- [6] C.J.T. Sewell "On the extinction of the sound in a viscous atmosphere by small obstacles of cylindrical and spherical form", Phil. translated by Roy. Soc London (A)210, 239-270(1910)UK.
- [7] Dennis A. Bohn "Environmental effect on the speed of sound" J. Audio Engineering Soc., Vol.36 NO. 4 p.p4 (1988) USA.
- [8] Gavin R. "Acoustical Properties of Air versus Temperature and Pressure" Department of Electrical and Computer Engineering, University of Queensland, **JAES Volume 42, Issue 11, pp. 927-933; (1994)** Australia.
- [9] Scott Penton, David Chadder, Seton Stiebert, and Valerie Sifton "The Effect of Meteorology and Terrain on Noise P propagation Modeling Methodologies Comparison of Five Modeling Methodologies", Canadian Acoustics, p.p30-33, Vol. 30, No. 4, (2002), Canada.
- [10] DENNIS A. BOHN, "Environmental Effects on the Speed of Sound" J. Audio Eng. Soc., Vol. 36, No. 4, (1988), (USA).
- [11] International Organization for Standardization (ISO), "ISO 9613/1 - Acoustics - Attenuation of sound during propagation outdoors – Part 1- Calculation of the absorption by the atmosphere," (1993). Switzerland.
- [12] <http://www.sengpielaudio.com/calculator-air.htm>.
- [13] Geln Ballou, "Handbook for sound Engineers 1st edition :the new Audio cyclopedia, " Chapter 2 p.p23, Howard W. Sams and Company, Audio Library (1987), USA.
- [14] B.L. Theraja, "A text book of Engineering physics :heat, light, sound and thermodynamics in SI units" chapter 41, p.p.669, S Chand and company LTD, (1987), India.
- [15] Walter Benenson, John W. Harris, Horst stocker and Hogler Lutz "Handbook of Physics" 4th edition, Chapter 10, p.p 324-325, Springer-Verleg -New York, (2002), USA.
- [16] Raymond A. Serway - John W. Jewett, "Physics for Scientists and Engineers 6th edition" chapter 17 p.p 512-542 Thomson Brooks/Cole(2004);USA.
- [17] G. Kirchhoff, Ueber den Einfluss der Waermeleitung in einem Gase auf die Schallbewegung", *Ann. Phys. Chem.*, vol. 6, pp. 177 -193, (1868)Germany.
- [18] weather Forecasting office in Salahdin Governorate.



Table (3) :The Meteorological data and acoustic absorption coefficients in Cinjar City .

Sound Source	Climate conditions (pressure p in Pas ,Air temperature T in centigrade , relative humidity H percent)	Absorption coefficients ranges A_a (dB/Km)
Motor cycle	<p>$p = 10047.948 \text{ pas}$ $T = 23 \text{ }^\circ\text{C}$, $H = 23 \%$</p>	1.4376↔2.5439
Rifle		2.03748↔2.504
Urban Traffic		2.5439↔5.5031
Car horn		2.5439↔5.5031
Conversion		2.2592↔93.888
Shouting		4.3827↔106.442
Motor cycle	<p>$p = 100447.948 \text{ pas}$ $T = 36 \text{ }^\circ\text{C}$, $H = 14 \%$</p>	1.67724↔4.160
Rifle		2.8226↔4.04636
Urban Traffic		1.67724↔6.090
Car horn		4.160↔7.85325
Conversion		3.36245↔98.168
Shouting		6.7↔110.9958
Motor cycle	<p>$p = 100338.137 \text{ pas}$ $T = 40 \text{ }^\circ\text{C}$, $H = 8 \%$, $h =$</p>	0.243188↔1.42534
Rifle		0.56232↔1.30
Urban Traffic		0.24318↔6.4010
Car horn		1.42534↔12.035
Conversion		0.807↔240.269
Shouting		8.359↔265.4225
Motor cycle	<p>$p = 100245.088 \text{ pas}$ $T = 40 \text{ }^\circ\text{C}$, $H = 9 \%$,</p>	0.220↔1.37665
Rifle		0.5185↔1.253
Urban Traffic		0.220↔6.2343
Car horn		1.37665↔11.132
Conversion		0.7546↔219.56
Shouting		7.945↔244