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ARTICLES

INFORMATION

FOREWORD

Application of acoustics is extremely important in human health management. This special edition contributed by experienced scientific engineers at various Indian research centers has revealed the insight information about the importance of the acoustics in Health aspects. A powered wheelchair is required for the independence of locomotors disabled persons. Use of acoustic signal is one of the ways of controlling the machine. An intelligent voice-based is developed here for collision avoidances. Malik and Singh have taken adequate safety measures in their design. In another paper, acoustic parameters like ultrasonic velocity and attenuation have been measured by Kirti Gandhi Bhatia et al, in mesenteric lymphoma in-vitro. Their study would assist in proper ultrasonic therapy planning for solid tumors and also differentiate these from mesenteric masses like inflammatory, benign, neoplastic and others in pre-therapy planning. Soni et al discuss the adverse health effects of noise pollution caused by firecrackers on Indian city during the special occasion like Diwali, social gathering, marriages, festivals etc. The long-term study on a variety of firecrackers from the Indian market indicates that the noise levels produced by most of the crackers are well above the 140 dB(C)pk. Mohana and Pratik Kumar describe the basic structure of ultrasonography transducer (also called probe), its types, functions, and improvement in design parameters related to medical ultrasound. Nishant Kumar et al had studied various features of SODAR technique that can be used for the social health. Analyses of the of the SODAR data along with the meteorological data reveal the level of air pollution such as good air quality, poor air quality or worst air quality. Singh et al had investigated therapeutic impact of Hindustani ragas on the level of depression in the Cerebrovascular Accident (CVA) and Diffuse Head Injury (DHI) Patients. Beck Depression Inventory (BDI) is used to assess the level of severity of depression of the sixty patients in different time intervals. Vinodhini and Geetha had measured and also presented a comparison of the sound pressure level (SPL) obtained across different stimuli (ISTS, Kannada passage, English passage, pure tone sweep and digital speech). Their study reveals ISTS for testing and evaluation of hearing aids in the context of Kannada and Indian English should be done with caution. Pradhan et al deal with measurement physical parameters such as density, ultrasonic velocity, apparent molar volume, apparent molar compressibility, adiabatic compressibility, partial molar volume, compressibility, specific acoustic impedance, intermolecular free length, salvation number, a relative association of Diclofenac and aceclofenac drugs in aqua-organic solvent media. These drugs are non-steroid anti-inflammatory drugs used for the treatment of osteoarthritis, rheumatoid arthritis, migraines and also used for relief of pain. Their study is helpful to understand the mechanism of drug action in the biological domain.

As I conclude this overview, I would like to thank Dr. Biswajit Chakraborty, Chief Editor of JASI for his support throughout the preparation of this special issue. I am also thankful to ASI Secretariat in particular to Dr. Mahavir Singh for his help in many ways. My sincere gratitude to the reviewers for their valuable inputs to improve the quality of the special issue. I acknowledge the reviewers (please see list at the end of the note) support providing valuable time to improve the quality of the presentations.

Dr. V. R. Singh

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A new voice based intelligent wheelchair

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ABSTRACT

A powered wheelchair is, generally, required for independence of locomotors disabled persons. Proper safety measures is important in commercial powered wheelchairs to prevent collision in dynamic environment. Use of acoustic signal is one of the ways of controlling the machine. An intelligent voice based is developed here for better collision avoidances.

1. INTRODUCTION

A wheelchair is an imperative vehicle for rehabilitation of locomotors disabled persons for short distance mobility[1]. Several investigations have revealed that children, adults and disabled persons benefit significantly from access of independent mobility vehicles[2, 3]. The available wheelchairs in literature are classified as - manual wheelchair, electrical powered wheelchair and intelligent wheelchair/smart wheelchair. Manual wheelchair are used for independent mobility and need human physical energy as well as human cognitionto propel and control the vehicle. Electrical powered wheelchair drivers for autonomous mobility primarily require human cognition for controlling the movement wheelchair[4]. The requirements of mobility disabled arefulfilled with traditional manual or powered wheelchairs but asection of the mobility disabled persons in society finds it hard or impractical to use wheelchairs independently[5,6]. In order to accommodate this population, researchers have utilized technologies originally invented for mobile robots to make intelligent wheelchairs for autonomous navigation[7]. Voice (acoustic) is most natural communication medium among the human beings. Several researchers are working on human machine interface by voice[8, 9]. Traditional Voice Control Wheelchair (TVCW) uses human voice as a direct method for driving the vehicle. Voice control mechanism is used with combination of sensors to identify and avoid obstacles in the wheelchair's path for the navigation assistance for a power wheelchair in the proposed intelligent wheelchair developed here. Design and performance evaluation results are presented here for new voice based intelligent wheelchair.

2. EARLIER WORK

The design and development of the intelligent systems have been always challenging for engineers and scientists. Different methods based on knowledge-based systems, neural networks, genetic algorithms, fuzzy logic and intelligent agents have been developed for intelligent systems having better intelligent capabilities. The level of intelligence of machines is continuously growing with the development in architectures, sensors, actuators, software, hardware, internet technologies and smart mobile phones.

A number of wheelchairs have been developed for elderly or physically disabled or cognitive impaired persons with different degrees of machine intelligence[2-19]. Simpson in 2005 gave literature review on smart wheelchair[7,8]. Nishimori *et al.,* developed a voice controlled wheelchair by voice commands in Japanese, such as "susume (run forward)". The experiment with three personnel was carried out in the campus room to demonstrate the usefulness of the system[13]. Kathirvelan *et al.,* developed an automatic voice command control low cost intelligent wheelchair for physically weakened people. The voice commands produced by the wheelchair user are processed with the intelligent scheme. The system is incorporated with ultrasonic sensor and IR sensor for obstruction detection and path ruling[14]. Qidwai and Shakir designed a cost effective ubiquitous Arabic speech language controlled wheelchair for rehabilitation aged patients and people with disabilities. Furthermore, they have more friendliness for their mother language. Hence, a voice/speech controlled system in Arabic language is made for their interactions with wheelchair more convenient to help in enhancing their living conditions[15]. Sivakumar *et al.,* proposed a voice controlled wheelchair robot system. The wheelchair can robotically navigate from one point to other in the home as per control from the voice input unit. The system is also equipped with obstacle evasion technique to avoid accidents[16]. Aruna *et al.,* proposed an intelligent wheelchair control with two means of inputs, i.e. acoustic recognition and touch screen. The arrangement wheelchair achieved movement in all direction with an accuracy of 94.6%. This dual control wheelchair helps the disabled person's movements in the indoor system[17]. Ruzaij *et al.,* explained the plan of voice process in three manners for intelligent scheme the movement and route of the wheelchair for the rehabilitation machine with a microcontroller unit[18]. Chauhan *et al.,* proposed a low cost voice based intelligent wheelchair with idea of Artificial Intelligence with Raspberry Pi for controlling the device, infrared and ultrasonic sensors for robust obstacle detection, USB microphone in support of voice input[19]. Avutu *et al.,* implemented plan of voice control unit for a power-driven wheelchair based on the speech processing method and navigation system. A microphone is presented to the user to utter the destination then the wheelchair robotically decides to the destination path. The result promises that the voice controlled wheelchair improves the quality of life of disabled population[20].

However, there are problems of collision avoidance mechanism in the existing systems. In order to solve these problems, a new low cost intelligent voice based wheelchair is developed with effective collision avoidance mechanism in unstructured and dynamic environment for cognitive impaired, elderly and disable persons for their quality life without care giving staff or family members.

3. DESIGN AND IMPLEMENTATION OF INTELLIGENT WHEELCHAIR

Voice commands are commonly used for controlling machines, mobile robots, apparatus and computers. In realized wheelchair, acoustic signal with machine reasoning capability is used to drive wheelchair to avoid collision. The wheelchair consists of voice recognition module (HM2007-based kit), three IR proximity sensor, AT89C51 microcontroller, H-bridge chip, DC motors and frame of wheelchair. The design of intelligent wheelchair has been with multi sensors, a microcontroller, software program for final decision and actuator for decision execution.

3.1 HM2007 based voice recognition kit :

The heart of voice recognition module circuit is the HM2007 chip, which is fabricated by HUALON Microelectronics Corporation, Taiwan. The chip distinguishes 20 acoustic terms, each word a length of 1.92 seconds.Acoustic samples are attained by a Microphone in kit. HM2007 analyzes the analog signal received compares with the data stored in external RAM and finally gives an output a corresponding 8 bit Data. This 8 bit data is directly connected to a port of Microcontroller for further action.

The HM 2007 based voice recognition module requires initial configuration or training of words, which is performed using a 4 × 3 Matrix Keypad. In the training process user trains, the IC by speaking words into the microphone and assigns a particular value for that word. For example a world "left" can be assigned a value 01. This can then be later connected to a microcontroller for further functions.

3.2 Hardware arrangement of intelligent wheelchair :

The devised wheelchair has four inputs. The first input is a HM2007 based voice recognition kit. It recognizes a human voice command as per it's training to give a digital output. The output is provided to a port of 8051 microcontroller. The three IR proximity sensors are used to logic the obstacle in surrounding of wheelchair. The user acoustic commands with other three picked information about obstacles in surrounding are used to take decision with reason for DC motors to implement correct command. This introduces safety feature in hardware design. This wheelchair is called intelligent wheelchair. The concept of system architecture is shown in Figure 1.

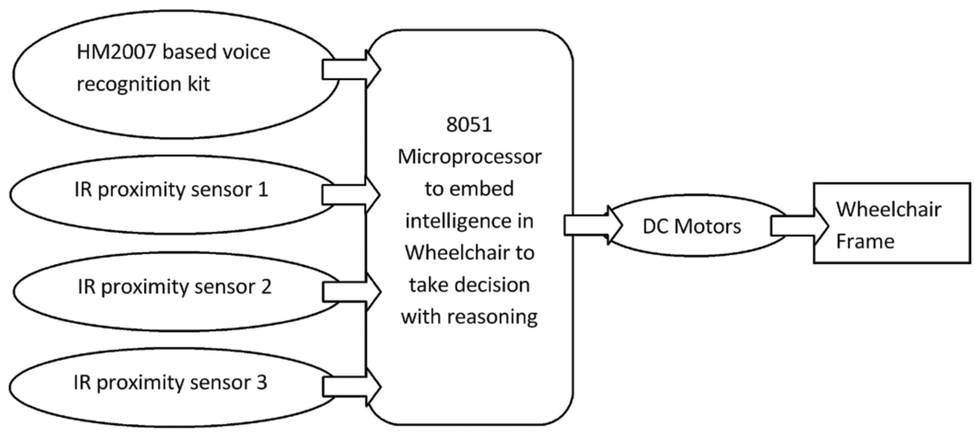

Fig. 1 Block diagram of proposed intelligent wheelchair

3.3 Reasoning intelligence :

Traditional voice control wheelchair is one voice based input. According to surrounding environment situations, human reasoning capabilities are used to take decision. No reasoning intelligence is embedded to the machine. However, traditional wheelchair may fail to avoid obstacle with cognitive weaken wheelchair user.

Therefore, a new wheelchair is developed with the concept of scientific inference engine (SIE)[10] to embed reasoning intelligence. As shown, there are four inputs to the wheelchair. Voice command input is based on user understanding of surrounding environment. For cognitive impaired user, input voice command may be incorrect for wheelchair and may cause accident. The three IR proximity sensors are used to pick the neighboring environment information. This information is compared with user command to give justified command to the wheelchair actuators. This technique avoids the chance of accident and make wheelchair more suited for cognitive impaired user without a care giving staff. This reasoning is embedded as assembly language program in 8051 microcontroller. This makes a low cost solution for collision avoidance in voice control wheelchair.

3.4 Intelligent wheelchair with actual hardware :

The details of used hardware are shown as Figures 2 to 5.

4. EXPERIMENT FIELD TRIALS AND PERFORMANCE RESULTS

Evaluation is made about the effectiveness of the developed intelligent wheelchair. Various field tests have been carried out at Renu Vidya Mandir (Institute of Special Education, Vocational Rehabilitation Training and Research), Sonepat. The subjects are with four care givers (physical and mental fit) and four children suffering from muscular dystrophy and cerebral palsy.

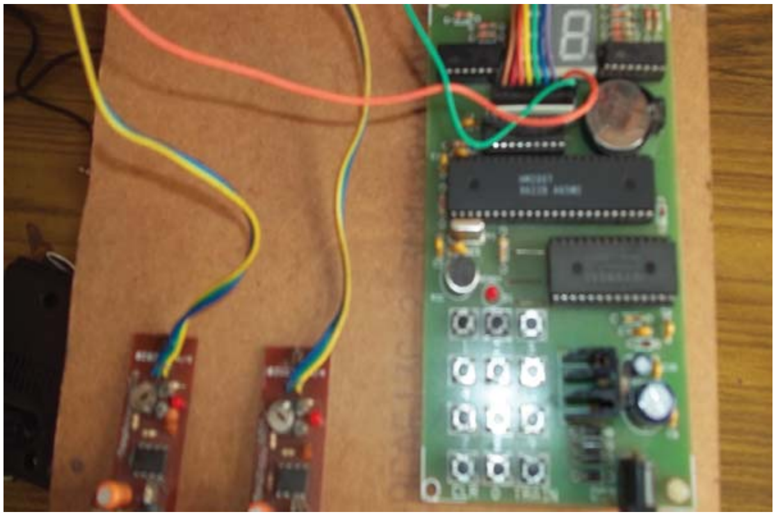

Fig. 2 IR sensors with HM2007 kit

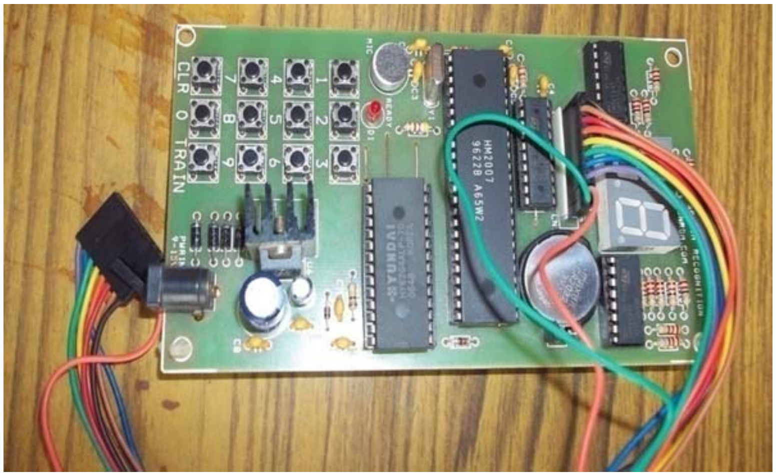

Fig. 3 HM2007 Kit Voice recognition module

Fig. 4 Tradtional voice control wheelchair

Fig. 5 Model of intelligent wheelchair

The exhibition of the working of intelligent wheelchair model is made among all participants. The participants are taught for using the prototype model. Firstly, trials have been conducted with care givers in presence of wheelchair user. The wheelchair has been tested for 20 voice command from each care giver and observations were recorded. Then, similar trials have been conducted with wheelchair user and observations have been also documented. The results of intelligent wheelchair are described as follows:

4.1 Results with wheelchair using voice command

The developed wheelchair had four inputs and SIE based software was embedded in microcontroller to decide the concluding navigation command for wheelchair. The LCD has been used to display the concluding command. The final command has been implemented by using H Bridge IC and DC motors.

Table 1. Results of intelligent wheelchairwith voice command.

Participant	Multi inputs		Final navigation command after SIE program to avoid collision success rate
	User voice command success rate in percentage of sensing the correct voice command with local reasoning using HM2007 as hypothesis for wheelchair navigation	Input from IR sensors as experiment(s) with local reasoning for wheelchair navigation	
Caregiver 1	75	Caregiver Independent	100
Caregiver 2	50	-do-	100
Caregiver 3	80	-do-	100
Caregiver 4	70	-do-	100
User 1	55	User Independent	100
User 2	50	-do-	100
User 3	40	-do-	100
User 4	40	-do-	100

Table 1 reports the observations of field testing of wheelchair using HM2007 kit to illustrate its autonomy with obstacle avoidance feature. The first column is about participants. The second column is regarding the results of usual success rate in percentage to sense the correct voice command by speech recognition system (trained HM2007 kit) by each participant. The IR sensor unit output result is independent of participant and is used to sense the external environment conditions. The voice command and IR sensor digital outputs are used to decide the final navigation command for wheelchair navigation. The final output navigation command is decided by SIE[10] that is the software program embedded in microcontroller. The fourth column describes that in all trials, the static obstacle is avoided. It demonstrates the effectiveness of developed intelligent wheelchair in obstacle avoidance in comparison of traditional voice control powered wheelchair.

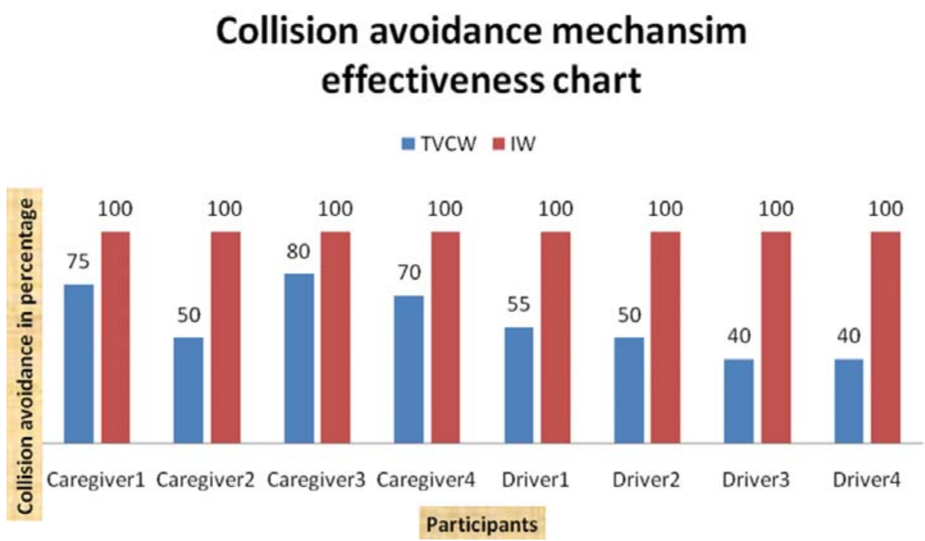

Fig. 6 Number of collision avoided by respective participants during navigation by employing EPW using HM2007 and CWNS based IWusing column bar chart.

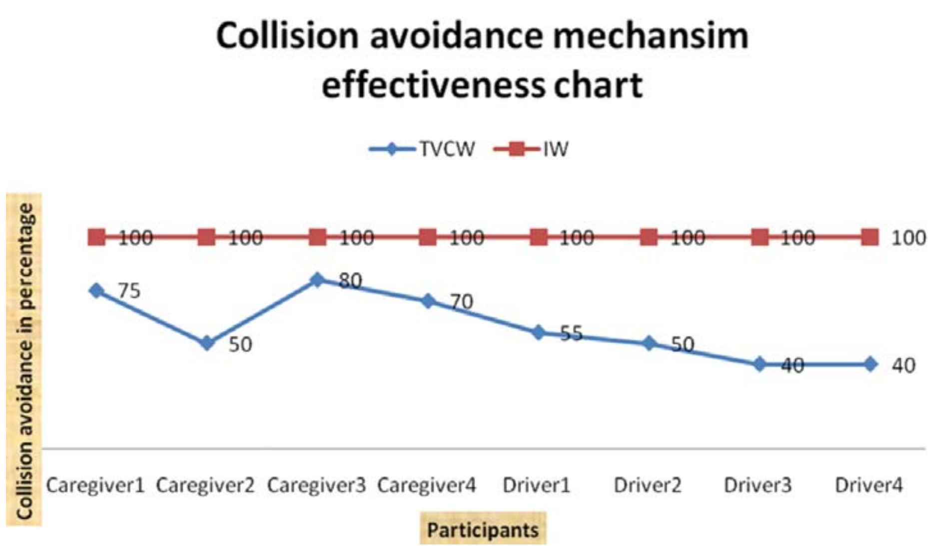

Fig. 7 Number of collision avoided by respective participants during navigation by employing EPW using HM2007 and CWNS based IW using line chart

In Figure 6, the results of electrically powered wheelchair using Traditional voice control wheelchair and intelligent wheelchair in term of collision avoidance with eight participants are shown. In Traditional voice control wheelchair with HM2007 kit, collision success rate depends upon voice quality of participants, limitation of HM2007 chip in perceiving the voice and user intellect to take correct navigation decision. The usual collision avoidance success rate using traditional voice control wheelchair by means of HM2007 with care giver, wheelchair user and average among all eight participants has been 67.5%, 46.25% and 57.5% respectively. In contrast to this, IW the collision avoidance success rate has been 100% with performed experiments. This has been demonstrated using four experience care giver, two adolescent wheelchair user of muscular and two children of cerebral palsy. This dramatically zero chance of collision is possible because of user independent inputs and comparing of these independent inputs with user voice input to implement the concluding navigation command to wheelchair.

Results shown in Table 1 are graphically shown in Figures 6 and 7 as bar chart and line chart respectively to display the improved difference.

5. DISCUSSION

The trials of developed models have been conducted with total eight participants in room environment. Four have been disabled children suffering from muscular dystrophy and cerebral palsy and the other four have been found to be fit. The test findings of intelligent wheelchairs conferred accident dodging rate 100% exact in contrast to 57.5%, 55% and 92% of traditional voice control wheelchair using HM2007 kit. This noticeable outcome has been achieved because of verification of user voice command with other inputs in the reasoning mechanism using scientific inference engine reasoning technique. This gives a low cost effective obstacle mechanism for voice control intelligent wheelchair for cognitive impairments type of disabilities in contrast to traditional or motorized wheelchairs.

6. CONCLUSION

A new voice based intelligent wheelchair has been developed with better collision avoidance. Comparative results are given with conventional existing wheelchairs to show better collision avoidance mechanism effectiveness.

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In vitro acoustic parameters of mesenteric lymphoma

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ABSTRACT

In order to identify the pathological features and making proper arrangement of ultrasonic therapy planning of benign, malignant and other tumours like lesions of mesentery, an ultrasonic study has been made on the mesenteric mass *in-vitro*. Acoustic parameters like ultrasonic velocity and attenuation have been measured in mesenteric lymphoma *in-vitro*. Ultrasonic velocity in these samples has been found to be in the range of 1669 ms^{-1} to 1697 ms^{-1} with mean value of 1681 ms^{-1} while attenuation ranging from 286 dBm^{-1} to 369 dBm^{-1} with mean value of 329 dBm^{-1}. It is known from earlier studies that attenuation is a good indicator of tissue pathology. However, the present study would assist in proper ultrasonic therapy planning for solid tumours and also differentiating these from mesenteric masses like inflammatory, benign, neo plastic and others in pre therapy planning.

1. INTRODUCTION

Benign mesenteric masses are rare and are misdiagnosed many times as the common neo plastic tumours of mesentery (Levy *et al.* 2006). It is difficult to differentiate these among malignant, benign or inflammatory (Levy *et al.* 2006, Wronski *et al.* 2011, Yenarkarn *et al.* 2007). However, pathologically different, accurate preoperative diagnosis is very difficult. A standardized differentiation between different diseases of mesenteric masses must be done before, and then ultrasonic therapy must be planned accordingly. For these solid tumours treatment, ultrasonic therapy is a technique where acoustic parameters play important role in identification, differentiation and therapy planning (Li *et al.* 2007).

Diagnosis of solid abdominal tumours near mesentery is sometimes confusing clinically, radiologically as well as pathologically due to overlapping features. This might result in inappropriate therapeutic decision. Efforts have been made earlier to find the difference between benign and malignant lesions of mesentery (Levy *et al.* 2006, Wronski *et al.* 2011) by other means. Acoustic parameters are not used earlier to make diagnosis for lymphoma in this organ. Lymphoma is the most common cause of mesenteric masses (Yenarkarn et al. 2007, Mueller *et al.* 1980) and is malignant. A common finding on Computed Tomography (CT) imaging of mesenteric lymphoma is termed the "sandwich sign" (Figure 1) (Ellermeier *et al.* 2013, Medappil and Raghukumar 2010). The sandwich sign appears as multiple rounded, mildly

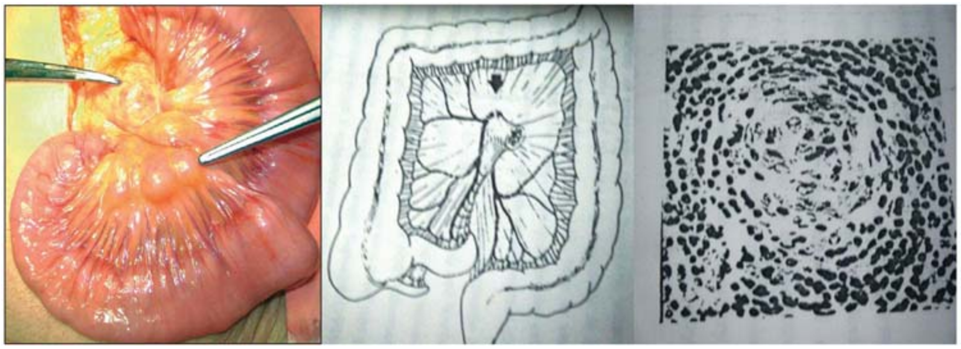

Fig. 1 Mesenteric mass (Lymphoma) Ref. Medappil and Raghukumar 2010, arrow showing the position of mesenteric mass near mesentery and its histological features

enhancing masses encasing mesenteric vessels. The mesenteric fat and tubular vascular structures serve as the "filling," and the homogeneous soft tissue masses serve as the "sandwich bun" (Ellermeier *et al.* 2013, Hardy 2003, Sheth *et al.* 2003). Correct diagnosis is confirmed by CT image-guided percutaneous fine-needle aspiration cytology (FNAC).

Here acoustic parameters pertaining to lymphoid mesenteric mass are measured exclusively to make an earlier diagnosis before therapy planning.

2. MESENTERY AND MESENTERIC MASS (LYMPHOMA)

Mesentery of small intestine or mesentery proper is a broad fan shaped fold of peritoneum, which suspends the coil of jejunum and ileum from the posterior abdominal wall. Mesentery is attached to the border which is 15 cm long and directed obliquely to the right. It extends from duodenojejunal flexure on outside of L_2 vertebra (IInd lumber) to the upper part of right sacroiliac joint. Free or intestinal border of mesentery is 6 meters long and thrown into plates. It encloses the gut (intestine) forming its visceral peritoneum. Breadth is maximum 20 cm in the central part but gradually diminishes towards both the ends. Near the intestinal border, it leaves oval or circular fat free translucent area called windows. Contents of mesentery are jejunal and ileal branches of superior mesenteric artery, and its accompanying vessels, automatic nerves plexuses, lymphatics, 100 - 200 lymph nodes and connective tissues with fat. As the mesentery contains a good number of lymph nodes (100-200), the enlargement of this structure may lead to mesenteric mass. The presentation of this mass depends on its etiology (Fine and Raju 1990).

Mesentery cysts are most often due to congenital lymphatic spaces that gradually enlarge as they fill with lymph. These may be divided into four groups based on their etiology: embryonic or developmental cyst, traumatic or acquired cyst, neo plastic cyst and infective or degenerative cyst. Neo plastic may be presented as solid mass as primary neoplasia of lymph nodes or secondary metastasis in the lymph nodes of the mesentery. Solid lymph node enlargement is most commonly by lymphomas (primary) which leads to formation of mesenteric mass (Fine and Raju 1990).

3. MATERIALS AND METHODS

3.1 Sample preparation

Five samples of lymphoid tissues of mesenteric mass were collected from department of pathology, King George Medical University, Lucknow, India of patients of age 35 to 45 years. Consent was obtained by the clinician for procedure and research. These types of tumours are not very common, so more specimens could not be found out. All samples were preserved in 10% formalin solution. Their parallel sections were made with scalpel. They all were hard and firm masses, cut with gritty sensation. In appearance these were pinkish-white and glistening on cut.

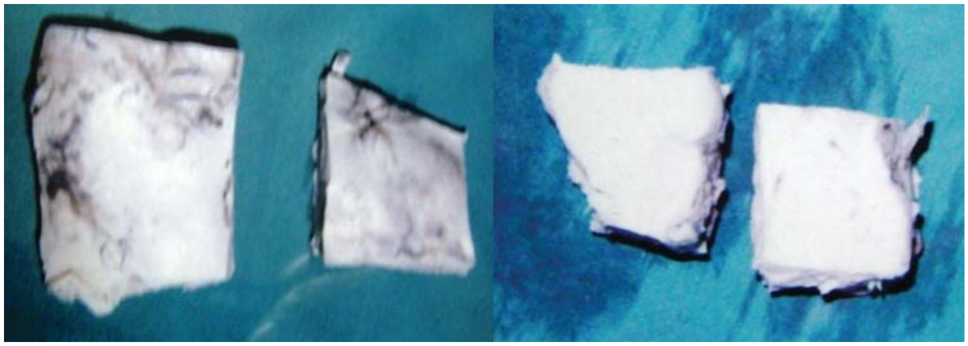

Fig. 2 Mesenteric Masses and their cut-sections

For calibration of instrument, standard samples of Perspex were used and results of ultrasonic parameters given in Table 1 were obtained by double-probe through transmission technique (Bhatia *et al.* 2001, 2002, Bhatia and Singh 2001, Singh *et al.* 2008). The accuracy for ultrasonic velocity and attenuation is ±0.5% and ±5% respectively, for the present measuring set up.

Table 1. Ultrasonic velocity and attenuation in Perspex by double probe through transmission technique for calibration.

S.No.	Thickness d cm	Ultrasonic Velocity v ms^{-1}		Attenuation α/f dB/cm/MHz	
1.	1.00	2675	2680*	1.93	2*
2.	1.50	2670		1.91	
3.	1.90	2667		1.97	

*Wells 1977

3.2 Method

There are various methods known and available in literature (Parker 1983) for measurement of ultrasonic properties in liquids and solids but the pulse method (Pellam and Galt 1946) has been extensively used for the measurement of ultrasonic velocity and attenuation in biological samples (Chivers and Parry 1978, Bamber 1997, Ghoshal *et al.* 2011) due to advantages of elimination of standing waves and minimization of local heating effects. The technique used in the present work is a double-probe through transmission as shown in Figure 3.

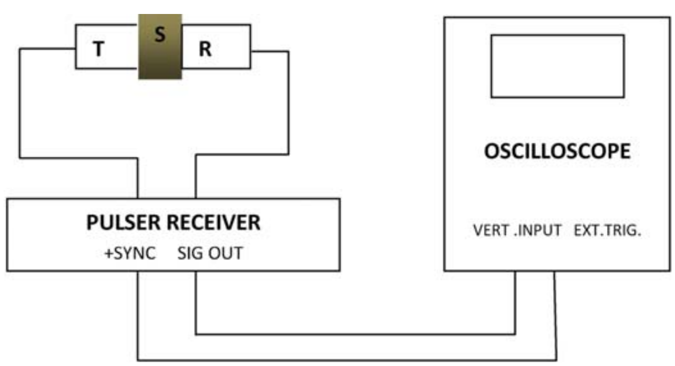

Fig. 3a Block diagram of double-probe through transmission technique for measurement of acoustic parameters- Ultrasonic velocity and Attenuation, T- Transmitter, R- Receiver, S- sample.

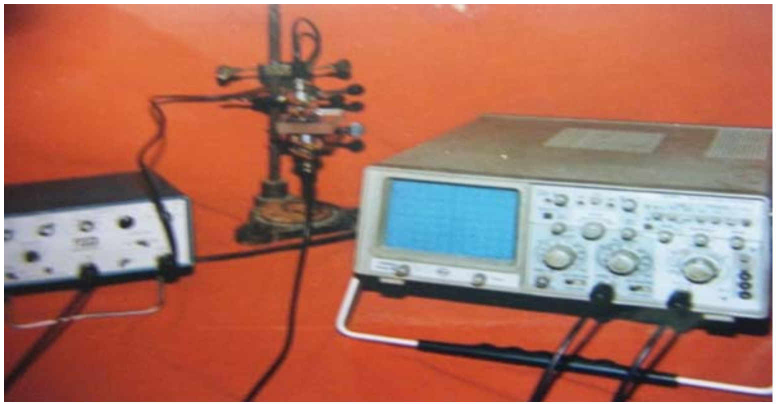

Fig. 3b A Double-Probe through transmission Technique for measurement of acoustic parameters

Sample was kept between two matched ultrasonic transducers as transmitter and receiver of same frequency (3.5 MHz) made at NPL, New Delhi, India by using discs (10 mm in diameter) of PZT-5 (lead zirconium titanate) material (Bindal *et al.* 1986). An ultrasonic pulser-receiver (Panametrics model 5052 PR) was used to excite the transmitting transducer. The pulses after passing through sample were received by another matched transducer then displayed on cathode ray oscilloscope (OS 300C-20MHz, L&T Gould make). Pulse transit time for known propagation distance was measured from the calibrated cathode ray oscilloscope screen that gave velocity. Attenuation was calculated using formula $\alpha = \{20\log (e_1/e_2)\}/d$, where e_1 and e_2 are the amplitudes in terms of voltage signals of the transmitted and received pulses, respectively and d the distance traveled by the pulse or thickness of sample. Densities (ρ) of samples were also measured by Archimedes's principle. Other parameters like acoustic impedance ($Z = \rho v$), dynamic modulus of elasticity ($E_d = \rho v^2$) and compressibility ($\beta = 1/\rho v^2$) were also determined using the measured values of density and ultrasonic velocity in the sample.

4. RESULTS AND DISCUSSION

The average values of ultrasonic parameters of selected five samples of lymphoid tissue of mesenteric mass are shown in Table 3.

Table 2. Average thickness of mesenteric mass samples.

Sample code	M1	M2	M3	M4	M5
Average Thickness cm	1.73 ± 0.02	1.76 ± 0.02	1.90 ± 0.01	1.79 ± 0.01	1.80 ± 0.00

Table 3. Ultrasonic velocity, attenuation and other parameters in mesenteric mass (lymphoma) at frequency 3.5 MHz, room temperature 26°C

Sample Code	Density ρ 10^3 kgm-3	Ultrasonic Velocity v ms^{-1}	Standard Deviation Ultrasonic Velocity v_{sd} %	Acoustic Impedance Z 10^6 km^2 s^{-1}	Dynamic Modulus Ed 10^9 kgm^{-1} s^2	Compressi-bility β $10^{10}kg^{-1}m$ s^2	Attenua-tion α dB/cm/MHz	Standard Deviation Attenuation α_{sd} %
M1	1.0355	1699	0.84	1.73	2.88	3.45	286	2.41
M2	1.0363	1679	0.57	1.74	2.92	3.42	326	3.95
M3	1.0384	1674	0.55	1.74	2.91	3.44	369	0.58
M4	1.0397	1697	0.15	1.76	2.99	3.34	294	1.37
M5	1.0422	1686	1.02	1.76	2.96	3.38	368	2.14

Ultrasonic velocity in these samples have been found to vary from 1669 ms^{-1} to 1697 ms^{-1} with mean value 1681 ms^{-1} and attenuation from 286 dBm^{-1} to 369 dBm^{-1} with mean value 329 dBm^{-1}. The attenuation values, a good indicator of tissue pathology show here little variation as compared to other abnormal soft tissues like uterus fibroids, breast carcinoma *etc.* (Kiss *et al*. 2011, Bhatia *et al*. 2001, 2002, Bhatia and Singh 2001). These are cake like structure of lymphoid mesenteric masses with low attenuation. In CT images also, lymphoma of the mesentery appears as lobulated mass with area of low attenuation representing necrosis that displaces bowel loops (Sheth *et al.* 2003, Yenarkern *et al.* 2007). The ultrasonic velocity and attenuation measured here may be used in differentiating lymphoma from other mesenteric masses with almost same appearance.

5. CONCLUSION

Mesenteric lymphomas are solid and uniform in nature. Lesser attenuation in these tissues as compared to breast, ovarian, uterine tissues and tumours is due to uniform characteristic. Other masses like cyst or fatty tissue have more water or fat content along with fibrous tissues and have more fat-fibrous tissue-water interfaces. These interfaces cause higher attenuation having different composition (Bhatia *et al.* 2001, 2002, Bhatia and Singh 2001, Bamber 1997). Ultrasonic propagation velocity is more in mesenteric mass tissues than the uterine, ovarian and breast tissues. This is due to the fibrous nature of these lymphoid tissues. These results are for in vitro fixed samples in formalin. In fact in vivo results are required to diagnose abnormality. However studies are needed on other type of lesions in the same region of mesentery also to standardize the acoustical parameters. Because of overlapping of radiologic appearances of fibrous tumours and tumour type lesions of mesentery, lymphoma, metastatic carcinoid, soft tissue sarcomas and primary gastrointestinal malignancies as given in different references(Levy *et al.* 2006, Wronski *et al.* 2011, Yenarkern *et al.* 2007), differentiation is vital preoperative. Attenuation is always found excellent indicator of tissue pathology. This parameter is needed to be studied more to find the various type of growth in this tissue as studied for other organ's tissues and for therapy planning.

6. AKNOWLEDGEMENT

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Fire crackers noise and its noise-induced hearing loss

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ABSTRACT

This paper discusses the adverse health effects of noise pollution caused by firecrackers on Indian city during the special occasion like Diwali, social gathering, marriages, festivals etc. Firecrackers create around 140 dB(C) pk of noise and noise at 85 dB(A) or above can damage hearing. During such occasion, the level of sound pressure level goes beyond 125 dB(A) which is as loud as Military jet aircraft take-off, whereas government limits Noise level at 55 dB(A) in the daytime and 45 dB(A) at night for a residential area. These types of noises do not only affect the Human beings but also the animals around us such as cats and dogs as they have ears that are more sensitive than the Humans. In the present study, a variety of firecrackers are analysed from the Indian market and from this long-term study, and it is found that noise levels produced by most of the crackers are well above the 140 dB(C) pk.

1. INTRODUCTION

Fire crackers play a very important role in our surroundings and culture. In different countries people use firecrackers to celebrate special occasions, social gatherings, festivals, marriages etc.. However the higher sound pressure level generated by firecrackers and the chemical used in the firecrackers can have negative effects on our environment. Firecrackers produce air and noise pollutions and various health problems. In India, many illegal crackers' units and stores are supplying firecrackers openly in the market with much higher decibels. These crackers are made by untrained workers and with the inferior material[1]. However, the Pollution Control Board (PCB) norms permit a limit of 125 dB (AI) at a four-meter distance for firecrackers; these crackers exceed the limit and violate the rule. This can lead to accidents. Officials of the Pollution control board (PCB) had constituted teams to carry out random checks on cracker stalls at various markets in the city to ensure they conform to pollution control norms. The crackers supplied by the different manufacturers are sent to the CSIR-National Physical Laboratory (CSIR-NPL), New Delhi. The CSIR-NPL has a laboratory facility that analyses each sample of firecrackers collected by the CPCB's officers. Once a sample arrives at the laboratory, its sound pressure level is examined to determine if it meets the CPCB's noise limits. If the firecrackers fail the tests, it is a banned hazardous substance. In the present paper, the sound pressure level of different firecrackers has been examined, and its health effect also discussed.

2. NOISE STANDARDS FOR FIRECRACKERS

The Noise standards for fire-crackers were notified by the Environment (Protection) (Second Amendment) Rules, 1999 vide G.S.R.682(E), dated the 5th October 1999 and inserted as serial no. 89 of Schedule I of the Environment (Protection) Rules, 1986. Subsequently, these Rules were amended by the Environment (Protection) Second Amendment Rules, 2006 vide G.S.R. 640(E), dated the 16th October 2006, under the Environment (Protection) Act, 1986. According to the Noise standards:

(i) The manufacture, sale or use of fire-crackers generating noise levels exceeding 125 dB(AI) or 145 dB(C)pk at 4 meters distance from the point of bursting shall be prohibited.

(ii) For individual fire-cracker constituting the series (joined firecrackers), the limit mentioned above shall be reduced by 5 log10 (N) dB, where N = number of crackers joined together. (http://www.cpcb.nic.in/divisionsofheadoffice/pci2/noiselimit_firecrackers.pdf)

3. CLASSIFICATION OF FIRECRACKERS

On the basis of intended use and degree of hazard potential, the firecrackers are classified into four categories (given in Table 1)[1]:

Table 1. Classification of firecrackers

Name of the Category	Details
Category 1	Firecrackers suitable for use inside domestic buildings
Category 2	Firecrackers which present a low hazard and are intended for outdoor use in a relatively confined area.
Category 3	Firecrackers which present a medium hazard and are intended for outdoor use in the large open area.
Category 4	Firecrackers which are incomplete and which are not intended for sale to the general public. These may be subjected to particular legal requirements regarding the acquisition, storage and use and are to be handled by professionals.

The firecrackers used for the present study belonged to Category two and three according to British Standard (BS-1988)[2] and collected by (Pollution control board, PCB) officers.

4. STANDARD MEASUREMENT PROCEDURE FOR FIRE CRACKERS NOISE

The firecrackers were pre-conditioned at 50°C for 24 hours to remove moisture as mentioned in the test method (Indian Noise Standards: noise limits formulated by the Ministry of Environment and Forest vide Gazette Notification No. 488, Part II Section 3-Subsection (i), dated October 5, 1999). The observations were conducted under controlled conditioned in the free field. The measurement site selected was a smooth, hard and horizontal stretch of concrete surface of 5 m diameter with no reflecting surfaces within 15 m distance from the point of the bursting site. 'B&K' Precision Impulse Sound Level Meters with microphones fitted on tripods, 1.5 m above the ground, with axis parallel to the surface of the test site and pointing to the firing position, were used to measure both A-weighted impulse sound level (½ - inch 'B&K' microphone) in dB(AI) and C-weighted peak sound level (¼ - inch 'B&K' microphone) in dB(C)pk. These sound level meters were placed at 4 m distance, horizontally, from the observation site and pointing to the firing position. Both the microphones and sound level meters had an extended flat frequency response, large dynamic range and faithfully responded to fast-rising impulsive sounds of short duration. The sound level meters were pre-calibrated using sound calibrator at the beginning of the measurement. The C-weighting has been specified in many European countries as the means of measuring peak sound information, and for the type of noise generated by fireworks, the dB(lin) and dB(C) would be almost identical. In the present study both dB(AI) and dB(C)pk readings were taken.

5. RESULTS AND DISCUSSIONS

The firecrackers of a different brand, manufactured by several units were tested for noise level in an open space at the CSIR-NPL. The sound pressure levels for different firecrackers are shown in figure 1 and table 2. The average A-weighted and C- weighted noise levels 126±6 and 142±10 have been observed respectively. The vertical bars in figure 1 and ± denote the standard deviations from the mean as more than one (excluding Automatic Rocket) samples of one type of cracker have been tested in the laboratory (no. of the sample given in table 2). Total Fifty-five (55) different type of crackers with 8 to 10 replicates were tested in the laboratory out of which 29% dB(C)pk levels and 73% dB(AI) levels violations from standard limit *125 dB(AI)* or *145 dB(C)pk* were observed. The highest and lowest noise level were 162±2 and 119±2 dB(C)pk and 133±1 and ±2 dB(AI) respectively. The observation results show that the firecrackers are not meeting the required standards. Additionally, the boxes containing the firecrackers do not specify the noise level in decibel units and category of crackers. This should be mentioned according to the Explosive Rules, 1983. It is observed that during Diwali firecrackers not only create noise but also produce air pollutants such as particulate matter can cause nose, throat and eye-related diseases. Air and noise pollution reach record levels during Diwali. Maximum firecrackers are as loud as 140 decibels or greater, as noise level exceeding 85 dB(A) can damage hearing. Exposure to higher noise level can lead to restlessness, temporary or permanent hearing loss, high blood pressure, and sleep disturbance. Firecrackers are made of chemicals and materials such as Cadmium, Lead, Chromium, Aluminum, Magnesium dust, Nitrates, Nitrite, Phosphates and Sulfates, Copper dust and generate Manganese dioxide fumes, Copper dust fumes, Carbon Monoxide, Potassium, Zinc oxide fumes, Oxides of nitrogen and sulphur, which may cause dizziness, abdominal cramps, vomiting, bloody diarrhea, weakness and convulsion, irritation of the lungs and influenza-like symptoms, euphoria, headache, eye irritation, narcosis, coma, pneumonia *etc.*[7,8,11].

Several studies[3-10] have revealed that firecrackers can have severe effects on people with many health problems and also firing crackers increase the concentration of dust and pollutants in the air. Therefore instead of firing crackers, festivals should be celebrated eco-friendly to save our environment and health.

Table 2. Sound pressure levels produced by firecrackers

Code of Crackers	Name of Fire Crackers	dB(C)pk	dB(AI)	No. of Samples
1.	Square	158±2	130±1	10
2.	Bird	152±2	127±1	10
3.	Cake	158±2	133±2	10
4.	Mini Bullet	156±2	130±1	10
5.	Hydro	150±2	128±2	10
6.	Bullet	159±2	133±1	08
7.	Lakshmi	154±2	130±1	10
8.	Classic	162±2	132±1	10
9.	Krishna	157±2	130±2	10
10.	Bijli	140±2	120±3	10
11.	Double Sound	156±1	130±1	08
12.	Triple Sound	155±1	130±1	08
13.	Seven Shot	140±1	121±1	08
14.	Arl. Out	136±1	117±1	10

Conted.......

15.	Garland	149±1	129±1	10
16.	Single Shot	141±2	127±2	10
17.	Single Shot	145±3	127±1	10
18.	Mini Bullets	145±3	124±2	10
19.	Chit Phut Delux	126±4	109±4	10
20.	Hydrogen Bomb	147±3	129±1	10
21.	Rangoli	127±3	108±2	10
22.	Hydrogen green	148±1	129±1	10
23.	Hydrogen green / DSR	147±2	128±2	10
24.	Nazi Green / CN	157±1	131±2	10
25.	Classic King Size	142±3	128±3	10
26.	Terminator Bomb Green	141±2	129±2	10
27.	Magic Fountain Mighty Atom	142±1	128±2	10
28.	Classic Bomb	142±1	129±1	10
29.	Hydro Foiled	142±1	128±1	10
30.	Liberty	139±1	122±1	10
31.	Mini Bullet	140±1	128±1	10
32.	Automatic Rocket	126	116	01
33.	Apsara Sky Shot	123±2	118±1	10
34.	Hydrogen Green	141±2	128±1	10
35.	Classic foil	139±1	122±3	10
36.	Hydro Green	137±5	129±1	08
37.	Standards 7 Shots	120±5	116±4	10
38.	Mini Bullets / CSK	137±2	128±1	10
39.	Turkey Electric Crackers	133±3	123±2	10
40.	Square Green / DSR	139±1	130±1	10
41.	Standard Rang Goli / PS	125±2	112±3	10
42.	Classic King Size Green / SS	144±2	130±1	08
43.	Cornation Mini Bullets / CC	134±2	125±1	10
44.	Magic Fountain Mighty Atom / CSK	140±2	130±1	10
45.	Automatic Rocket / CSK	119±2	112±2	08
46.	Timing Flash / CFW	141±2	129±2	10
47.	Atom Bomb Green / SS	139±3	127±2	10
48.	Atom bomb foils / SS	140±3	128±1	10
49.	Hydro bomb / Hydro Green	142±4	130±4	10
50.	Bomb foils	139±3	127±2	10
51.	Atom bomb	141±3	129±2	10
52.	Hydro bomb foils	139±1	127±2	10
53.	Big bullet Bomb / KG	138±2	127±2	10
54.	Mighty Atom Flower	138±1	127±2	10
55.	Sun 100 Wala	137±3	126±1	10

6. RULES IN DIFFERENT COUNTRIES

In U.S. Consumer Product Safety Commission (CPSC) has issued obligatory safety regulations for firecrackers. According to these regulations, it is a violation of Federal law to import, distribute or sell fireworks that violate CPSC regulations and buyer fireworks have warning labels describing the hazard and function of firecrackers. In Finland, firecrackers are generally sold in last week of December from 25th to 1st January, and their use is allowed only on New Year's Eve from 18:00h to 02:00h the next morning. Similarly, in Germany, fireworks are available for purchase before New Year's Eve, permitting families to have their individual celebrations in their courtyard. In Iceland, fireworks are sold 28th - 31st

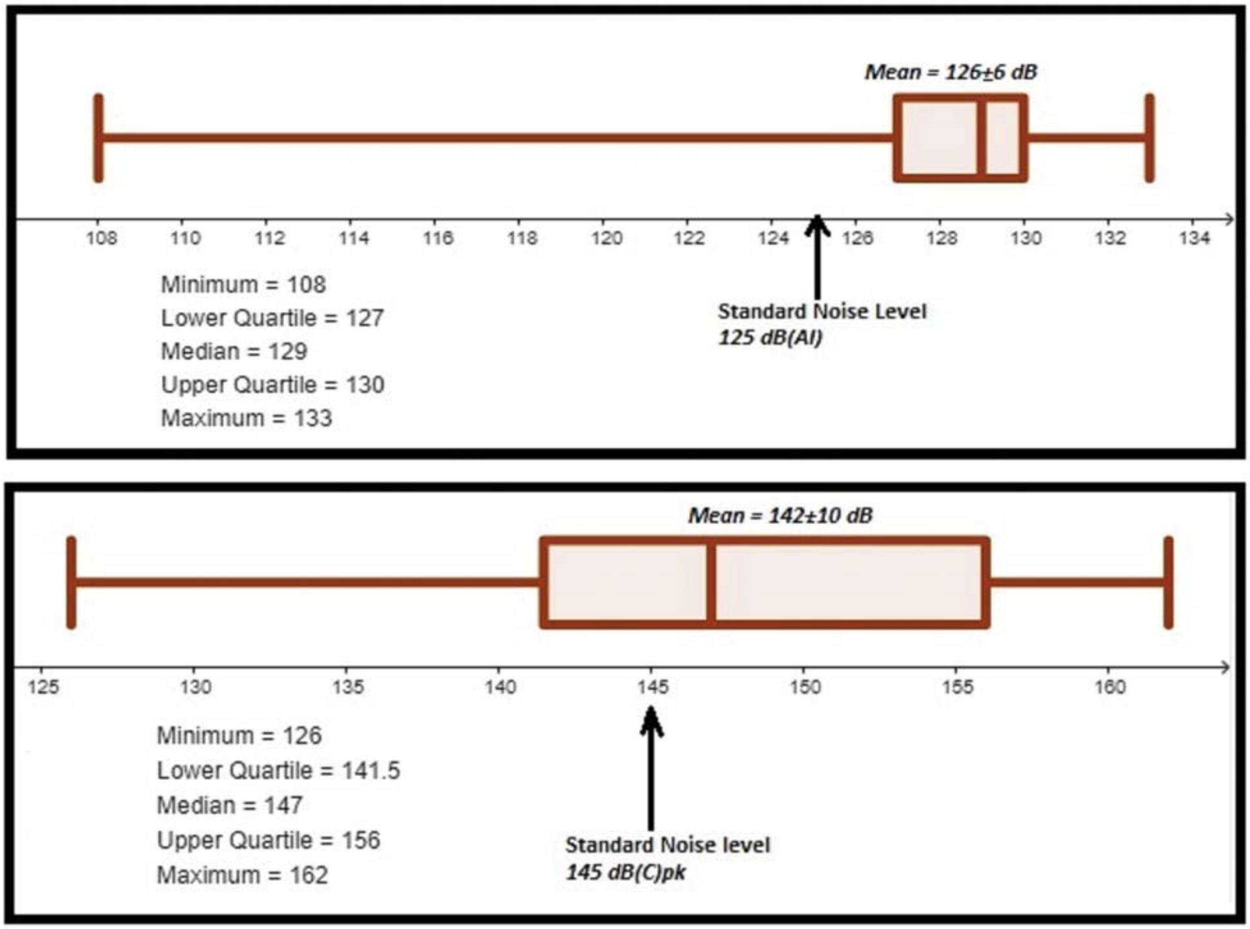

Fig. 1 A-weighted and C-weighted average sound pressure level for different firecrackers.

December and again on January 6. In the Netherlands, there is also some rules and regulations such as firecrackers can be sold to anyone age of 16 or older and are only sold in the last three to four days in December and in Norway, persons can only purchase fireworks 18 or elder and category 1, 2 and 3 fireworks are for sale from December 27-31 December and can only be fired between 18:00h and 02:00h on New Year's Eve.

7. NOISE EXPOSURE - ACCEPTABLE LEVEL AND DURATION

Exposure to sound pressure level should be well-ordered to the exposure is lesser than a maximum combination of exposure level (L in dB(A)) and time duration (t in minutes) (NIOSH -National Institute for Occupational Safety). Noise exposure permissible level and time duration are given in table 3. The maximum time of exposure at a sound pressure level can be estimated as:

$$t = 480 / 2^{(L - 85)/3} \tag{1}$$

where 3 is the exchange rate (dB), and 85 is the recommended exposure limit - REL (dB(A)).

8. NOISE-INDUCED HEARING LOSS IS IRREVERSIBLE

High level of sound pressure for any time duration causes fatigue of the ear's sensory cells. As a result, a ringing sensation in the ear and impermanent hearing loss observed. A similar condition has been

Table 3. Noise exposure permissible level and time duration (www.engineering toolbox.com).

Noise Exposure Level dB(A)	Duration Time		
	Hours	Minutes	Seconds
85	08		
86	06	21	
87	05	02	
88	04		
89	03	10	
90	02	31	
91	02		
92	01	35	
93	01	16	
94	01		
95		47	37
96		37	48
97		30	
98		23	49
99		18	59
100		15	
101		11	54
102		09	27
103		07	30
104		05	57
105		04	43
106		03	45
107		02	59
108		02	22
109		01	53
110		01	29
111		01	11
112			56
113			45
114			35
115			28
116			22
117			18
118			14
119			11
120			09
121			07
122			06
123			04
124			03
125			03
126			02
127			01
128			01
129			01
130			01
140			<1

observed when a person is listening to loud music, and the hearing develops as the sensory cells improve. It the exposure is loud, and for a longer time or regular, it can cause permanent, irreversible hearing loss. The high pitched or high-frequency sound are impacted first and is not noticeable instantly, but continuous exposure leads to hearing loss, negative impact on quality of life and affecting speech ability. Noise-induced hearing loss affects social life, workability and produces psychological stress and anxiety in a human being. Insufficient hearing protection during activities such as burning firecrackers or enjoying to loud music may cause substantial communication problems later in life[12-17].

9. CONCLUSION

It is observed that in most of the cases firecrackers noise level exceeding the standard limit. Although, the Central Pollution Control Board of India has banned firecrackers with a decibel level of more than 125 dB(AI) and 145 dB(C)pk at a distance of 4 meters from the bursting point. Therefore, considering the well-being of the people, the manufactures should be instructed to reduce the noise levels produced by these crackers either by reducing the charge content or altering the confinement techniques'. Keeping in mind the adverse effect of firecrackers on health's as noise pollution is as dangerous as the Air pollution. It is not only injurious to humans but also for other beings such as animals and birds. Animals whose ears are more sensitive such as Dogs and Cats get afraid and often lose their hearing ability. Here it is advised to all to encourage crackers free festivals celebrations or celebrations shifted to laser shows instead of using traditional firecrackers.

Overall, general awareness about noise pollution and its health hazards must be created among the general population by conducting regular public health campaigns. Future research studies should be targeted towards designing new protocols and protective equipment for preventing noise-induced health hazards. Some Indian research institute such as the Council of Scientific and Industrial Research (CSIR), the Central Pollution Control Board (CPCB), the National Environmental Engineering Research Institute (NEERI) and the Central Electronics Engineering Research Institute (CEERI), already started to work on development of green crackers with the help of government. Scientists in India are also developing electronic crackers to promote a smokeless and pollution-free Diwali. The e-crackers will produce light and sounds like conventional crackers. China already developed a non-polluting environmentally-friendly firecracker that reduces smog and fumes.

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Medical ultrasonography transducer

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ABSTRACT

Medical ultrasonography has attracted a lot of attention due to its largely harmless character, ease in use and economy involved during medical imaging. Ultrasound is generated and received in transducer making it a very important hardware. This paper describes the basic structure of ultrasonography transducer (also called probe), its types, functions and futuristic scope.

1. INTRODUCTION

Ultrasonography is the imaging using ultrasound waves. Ultrasound describes the sound waves with frequencies above the range of human hearing called human audible range, *i.e*, more than 20 kHz (>20 kHz). Detection of objects with the help of ultrasound has been used in animals, bats & porpoises for locating prey and obstacles. Although the phenomenon of ultrasound was discovered long back its use in technology and more so in medicine didn't pick up the pace for quite some time. Probably the unsuccessful use of ultrasound in locating the sunken ship Titanic in 1912 was its one of the first big-ticket industrial use. World War II gave the philip to the use of ultrasound in SONAR (Sound Navigation And Ranging) and quickly the opportunity was lapped up in the medical imaging due to the advancement of associated technology[1-7]. The use of ultrasound may be categorized as in Fig 1.

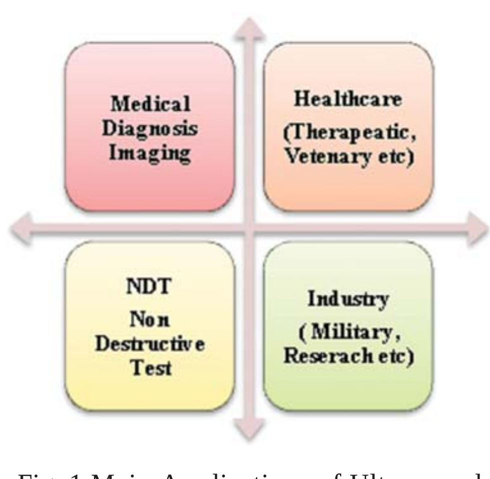

Fig. 1 Main Applications of Ultrasound

2. MAIN APPLICATIONS OF ULTRASOUND

Industrially, ultrasound has been applied in many areas like food, drugs, medical device industry, gas compression, cleaning surfaces, mixing, plastic & metal welding and to accelerate chemical processes. In 1960s ultrasound inspection of welded joints became an alternative to radiography for Non Destructive Test (NDT).

It eliminated the ionizing radiation and was cheaper too. NDT uses ultrasound to find flaws in materials and to measure the thickness of objects and their sizes and identify the location of the imperfection. In these applications frequencies of 2 to 10 MHz are commonly used. However, application for some special purposes uses other frequencies as well. A lower frequency of 50 to 500 kHz is used to inspect less dense materials like wood, concrete, and cement[8]. Ultrasonography has been increasingly used in a number of applications in medicine in diagnosis, surgical and therapeutic processes. During surgery bedside, ultrasonography is commonly used by surgeons in their day-to-day practices. In the 1960s there were reports of the use of ultrasound in therapeutic applications. It was applied to the potential of a highly focused beam to destroy the cells of the vestibular organ in the inner ear that caused severe vertigo. It was also used in cataracts, hypophysectomy, ablation of the substantia nigra in the treatment of Parkinson's disease, removal of warts and the treatment of laryngeal papillomatosis[11,12]. Diagnostic ultrasonography was first introduced in the obstetrics, and after that its use has expanded exponentially in all the fields of the medicine. It has varied applications in different areas such as gynecology, cardiology, neurology, urology and cancer detection. Medical ultrasonography is a medical imaging to visualize muscles, tendons, internal organs and their sizes, structure, and their pathological lesions. Clinically, it has evolved in Doppler ultrasound, interventional ultrasonography, contrast ultrasonography, molecular ultrasonography, elastography and compression ultrasonography. Ultrasonography is noninvasive, has good visualization characteristics and is relatively easy to manage along with being less expensive when compared with other imaging techniques like radiography, MRI, and CT. As ultrasound at diagnostic level is considered safe it has become the only modality of practically available imaging technique in prenatal care[2-7].

3. IMPORTANCE OF MEDICAL ULTRASOUND

Medical use of ultrasound may be categorized as therapeutic and diagnostic. Therapeutic ultrasound may have the low frequency (20 to 100 kHz), intermediate (20 kHz to 3 MHz) and high frequency (1 to 3 MHz). Low-frequency ultrasound is used to cut through bone and soft tissue such as in thyroid or tonsil surgery. High power therapeutic ultrasonic has been mostly used in biochemistry and microbiology laboratory. USA FDA has approved High Focused Ultrasound (HIFU US) for ablation of the uterine tumor and prostate cancer by heating them to 600C. Lithotripsy uses ultrasound to break kidney stones up. Physical therapy uses ultrasound in mobilizing tissue after orthopedic injuries[11-15].

Diagnostic medical ultrasonography uses high frequency (2 MHz up to 15 MHz). It is used to image and examine the uterus, ovaries, liver, kidneys, spleen, thyroid, scrotum, pancreas, gallbladder and bladder. It is useful in visualizing inside the heart and to determine any blockages, abnormal structures, measuring blood flow, detecting kidney stones and tumors. Higher ultrasound frequencies are attenuated easily and hence can't penetrate through the body parts much, Therefore, high-frequency ultrasound is used to investigate superficial body structures. Ultrasonography (US) with 2.5 to 3.5 MHz frequency may image organs at depth like in abdomen, obstetrics, and gynecological imaging. 5 MHz US is used for vascular, breast and pelvic imaging, while 7.5 to 15 MHz is good for breast, thyroid, superficial veins and musculoskeletal imaging. For the production of all these specific ranges of US frequency, we use specific ultrasound transducers[3-7].

4. MEDICAL ULTRASONIC TRANSDUCER

US transducer is a device which can produce ultrasound energy and may detect it as well. It is comprised of a piece of a piezoelectric element or may have a number of such elements. Piezoelectric crystal can convert mechanical vibration into an electrical signal and vice versa. Quartz is a natural piezoelectric crystal while ceramic Lead Zirconate Titanate (PZT) and plastic Polyvinylidene Difluoride (PUDF) are synthesized. Natural quartz crystals are used in quartz watches to produce mechanical vibration. Lithium Sulphate and Barium Titanate also have piezoelectric effect. Ultrasonic transducer has worked almost exclusively according to the piezoelectric effect. The piezoelectric effect was described by the Curie brothers in 1880s when they found that an electric charge appeared on electrodes placed on a compressed quartz crystal. The piezoelectric crystal is the most important component and it is located near the face of the transducer. The front & back both faces of the crystal are coated with a thin conducting film to secure good contact with the electrodes. When mechanical stress or force are applied to these materials along certain planes, they produce an electric voltage on perpendicular planes. The electric voltage produced so may be measured easily which also may be taken as the surrogate measurement of the stress or force. An ultrasound transducer assembly has been shown in Figure 2. The piezoelectric crystals are thin (fraction of a millimeter) which are sandwiched between the matching layer in front and a Damping block on the backside.

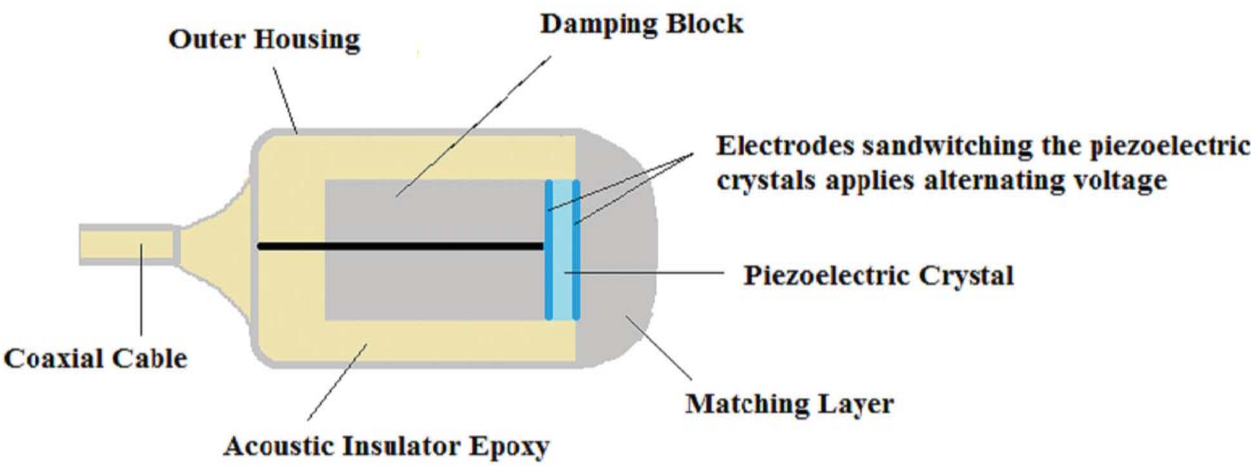

Fig. 2 Parts of the ultrasound transducer

Ultrasound transducers are generally designed to be most sensitive to its natural frequency, also called resonant frequency which is determined by the thickness of the crystal equal to $\lambda/2$, where λ is the wavelength of US in the piezoelectric element. When a voltage spike (a high voltage of about 150 Volt for a microsecond duration) is applied the crystal contracts first and then vibrate at a natural resonant frequency. For example, a 1 MHz transducer made of PZT (in which the speed of US is 4000 m/sec) will produce wavelength $\lambda = 4000\ /10^6$ meters = 4 mm. The thickness of PZT crystal required to produce 1MHz resonant frequency = $\lambda/2 = 4/2 = 2$ mm. Similarly, for a 2 MHz resonant frequency, the thickness is 1mm. It is to note that as resonant frequency increases the crystal becomes thinner. Piezoelectric crystals may be designed to vibrate in thickness or radial mode. Crystals in medical transducer are designed to vibrate in thickness mode.

The ultrasonography transducer may be made of the piezoelectric crystal (or array of such crystals) sandwiched between a pair of electrodes where the backside electrode is connected with a live wire while the front side electrode is grounded. The back side electrode (or coating) is blocked with a block called Damping Block or Backing Block. The front side electrode is juxtaposed with Matching Layer which is the interface with the piezoelectric element and the body tissue. The whole arrangement is placed in a metal shield which, in turn, is housed in a plastic case. An acoustic insulator Epoxy or similar material prevents the electrical interferences from passing on the probe housing. The electric energy is provided through a coaxial cable [3-5,12-17].

4.1 Damping Block

Damping material is made of a combination of tungsten and rubber powder in an epoxy resin and absorbs the ultrasound energy going towards the backward side. It also attenuates stray US waves scattered from the housing. It is obvious that the Damping Block is made in such a way that it absorbs maximum energy falls upon it and does not reflect back any significant portion. It is achieved by varying the ratio of tungsten and resin so that Acoustic Impedance of Damping Block becomes nearly same to that of the piezoelectric element. Mixing of rubber powder increases the ultrasound attenuation.

Damping Block dampens the vibration of the piezoelectric element (or US transducer) so that US produced has shorter spatial pulse length (SPL). SPL depends upon the central frequency emitted by the crystal and the damping block. SPL is defined as the product of wavelength and the number of the cycles of ultrasound produced by one pulse. For discerning the two objects by ultrasound it is essential that returning echoes should not be overlapped with each other and should be distinct. Therefore, shorter the pulse higher the axial resolution. Minimum distance between two objects must be ½ SPL so that they are identified distinctly in ultrasound. In such case reflecting echoes are SPL distance apart since sounds cover the distance twice in going and returning. Resolution may be increased by decreasing pulse duration, by limiting the number of cycles produced and by reducing the wavelength. Heavy damping block will reduce the pulse length and number of cycles both. The piezoelectric crystal produces various frequencies and hence ultrasound produced by it is not monochromatic in nature. The variation of amplitude of the vibration of a typical piezoelectric element with respect to the frequency of the applied voltage has been shown in Figure 3.

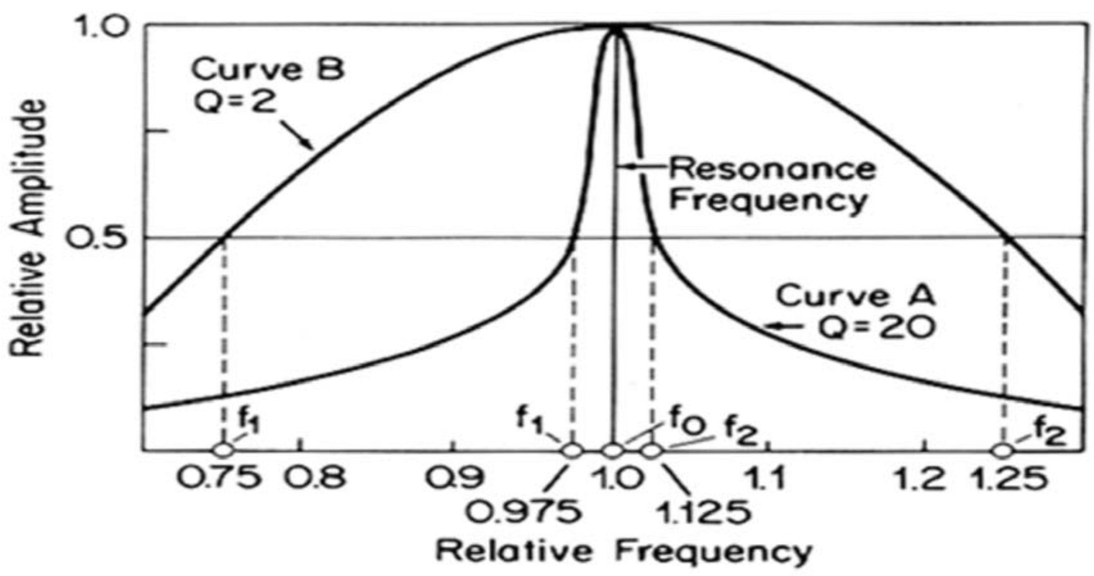

Fig. 3 The Q factor related to frequency response for a high Q (curve A) and a low Q (curve B) transducer. The figure has been taken from reference 4.

The purity (or sharpness) of the vibration produced by the piezoelectric crystal is denoted by 'Q Factor' which is defined as :

$$Q = \frac{\text{Resonant Frequency}}{\text{Full Width at Half Maximum (FWHM)}} \quad (1)$$

$$= \frac{f_0}{f_2 - f_1} \quad (1a)$$

$$= \frac{f_0}{\text{Band Width}} \quad (1b)$$

A high Q ultrasound probe emits the narrow range of frequencies and hence more pure. On the other hand, low Q transducer produces a whole range of frequencies. In Figure 3 one can see that high Q transducer produces narrow bandwidth. Q also denotes the length of the time sound (vibration) continues. It is also called ringing which is similar to the one strike on a bell and subsequent continuation of the sound (ringing). High Q transducer has a longer duration of ringing which is also called longer Spatial Pulse Length (SPL) and low Q transducer has shorter SPL (Fig 4). Shorter SPL provides better axial resolution and hence shows details in imaging.

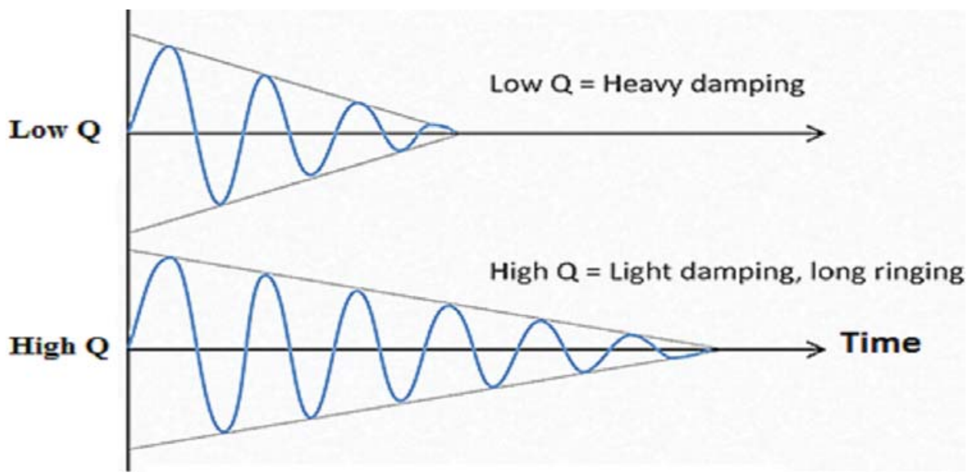

Fig. 4 Ringing from high and low Q transducer

Heavy Damping Block rings down the persistence of the sound making SPL short. However, It produces a broad band of frequencies and reduces the purity of the sound produced. Such heavily damped transducer has low Q factor. General ultrasonography needs broad bandwidth (and hence high axial resolution). On the other hand, Doppler ultrasonography transducer which measures the velocity of the blood needs high Q to read velocity information from the changes in echo frequency. Similarly, continuous wave ultrasound probe contains high Q. It should be noted here that 'Q' factor denotes the characteristics of the ultrasound waves a transducer produces which may make them suitable for the specific tasks. Low 'Q' does not indicate poor quality of the ultrasound signal produced by such transducers [3-7].

4.2 Matching Layer

Generally, there is a great difference in the acoustic impedance of the ultrasonography transducer and that of the patient's body. Due to this mismatch, the US energy will not transmit into the body and will reflect back at the interface. To minimize this mismatch the manufacturer places layers of materials in front of the piezoelectric element with acoustic impedance intermediate of a transducer and soft tissue. This is called matching layer. The acoustic impedance of matching layer is generally geometric mean of acoustic impedance of the transducer and the soft tissue and may be given as

$$Z_{\text{Matching layer}} = (Z_{\text{Transducer}} \times Z_{\text{Soft Tissue}})^{1/2} \quad [2]$$

Matching layer may be made of an aluminium powder mixed with resin.

The thickness of the matching layer must be equal to the one-fourth of the wavelength of ultrasound in the matching layer. It is termed as "quarter wave" matching. If the speed of ultrasound in matching layer is 2000 m/sec the wavelength for a 1 MHz ultrasound in matching layer will be $\lambda = 2000/1\times10^{-6}$ m $= 2 \times 10^{-3}$ m = 2 mm. The thickness of the matching layer required = $\lambda/4 = 2/4$ mm = 0.5 mm to the compression wave arrived from opposite face and hence adding them and at the. Matching layer with thickness $\lambda/4$ or odd multiple of $\lambda/4$ (*i.e.*, $3\lambda/4$, $5\lambda/4$ and so on) provides opportunity to the acoustic waves to be in phase. In such situation compression waves add to the compression wave arrived from opposite face. At the same time waves which are not in phase will cancel out each other[3-7].

5. TYPES OF TRANSDUCER AND THEIR USES

Medical ultrasonography transducers have evolved over the period of time into many types offering various modes of operations and image formats. Most of the ultrasonography transducer employs a number of piezoelectric elements stacked next to each other (called arrays) in the place of single piezoelectric crystal. In an array, the number of piezoelectric elements may vary from 128 to 512. The individual piezoelectric crystal may have a thickness equivalent to $\lambda/2$ (λ = wavelength of US in piezoelectric crystal) and height of several millimeters (usually 2 × 10 mm). The array or assembly of piezoelectric elements may be activated sequentially or all at the same time. In the former, a small group of element is fired (or electrically activated) at one time. It is also called Linear Arrays. On the other hand, the mode where all elements are fired simultaneously is called Phased Array [3-5, 21, 22].

5.1 Linear Array

In a linear array, a number of piezoelectric elements (usually 256 to 512) are lined up adjacent to each other but only a small group (usually 20) of adjacent elements are activated at a time leading to the rectangular field of view (FOV). The effective transducer width is the combined width of all simultaneously activated elements. The reflecting echoes are received by all elements in the assembly. Such firing of a small group of elements simultaneously provides better resolution. For a pulsed sequence of firing, another group of elements is fired displaced by one or two elements and so on. Linear transducer is used for imaging small parts and shallow structures like eyes, vessels etc. In case of such transducer the image is generally rectangular which is used in vascular imaging and in some abdominal imaging. Convex curvature linear array may produce useful sector imaging format suitable for deep abdominal imaging [3-5, 21-23].

5.2 Phased Array

A phased array ultrasonography transducer contains 64 to 128 piezoelectric elements and hence is physically smaller than a linear array. All elements are fired nearly simultaneously producing a sector scan. By introducing a slight time delay in electrical activation (firing) of elements the ultrasound beam may be steered back and forth across the patient without moving the transducer physically. Due to this ability phased array transducers are used in cardiac imaging and evaluation of vessel pulsation in abdominal ultrasonography. The small foot print of phased array makes it suitable for imaging between the ribs (trans-thoracic imaging) and endocavity imaging from esophagus, gastro-intestined tract, rectum and vagina etc. For example, three dimensional imaging of heart from esophagus may be carried out by using phased array US probe attached to a gastroscope [3-5, 21-23].

5.3 Multifrequency Broad Band Transducer

The modern ultrasonography transducer may be a multifrequency transducer which may produce almost 80% bandwidth (i.e., ± 40% on either side of the central frequency). For example, if the central frequency is 5 MHz, the multifrequency transducer produces frequencies from 3 MHz to 7 MHz. For such transducer, a number of smaller PZT rods are machined on the base of PZT. Epoxy is filled in gaps among the PZT rods to give it the smooth surface. Such multifrequency transducer has acoustic impedance near to that of the tissue and hence obviating the need for multiple matching layers [3-6].

5.4 Capacitive Micromachined Ultrasonic Transducer (CMUT)

CMUT are silicon-based electrostatic transducers which are essentially capacitors with a fixed electrode and a free electrode. The fixed electrode is backplate while membrane forms the free electrode. Application of a voltage between two electrodes set the membrane vibrating leading to ultrasound. The geometric and mechanical properties of these capacitors may be controlled by using fabrication technology of integrated circuitry. CMUT may produce even further wider bandwidth with high resolution and are future of the transducer at present. CMUT transducer may be designed from the size of 100 ?m to 3cm size arrays commanding frequency range of 10kHz to 60MHz. 100 μm sized transducers are used for intravascular applications while 3 cm sized arrays are applied in non invasive therapy[24]. CMUT has been used for imaging as well as therapy purposes. For the later application CMUT is used for therapeutic ablation of uterine fibroid, liver cancer, brain tumours, bone ailments etc using High Intensity Focused Ultrasound (HIFU). For therapeutic application CMUT may produce surface acoustic output pressure as high as 1.7-02 MPa at 2.5MHz[25].

6. CONCLUSION

Ultrasound transducer is the heart of the ultrasonography since it is the source of ultrasound energy. The imaging and image quality is much affected by the type of transducer used and therefore future of medical ultrasonography also depends upon the advancement in transducer technology.

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SODAR as a diagnostics tool for urban air-quality and health care system

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ABSTRACT

SODAR (SOund Detection And Ranging) is an important tool for the measurement of Atmospheric Boundary Layer (ABL) which is a main meteorological parameter for the dispersion modelling concerning the air pollution. SODAR can be used as a diagnostics tool in the air quality management as by using SODAR structure at different level of pollution such as good air quality, poor air quality or worst air quality can be identified. It can also be used to determine the pollution loading capacity of the specific region by measuring the Ventilation coefficient. In the present paper, various features of SODAR technique that can be used for the social health have been discussed. Along with the SODAR data, meteorological and air pollutants data also analysed and studied.

1. INTRODUCTION

Human beings are directly influenced by the natural process of atmosphere like cutting the forest, increase in urbanisation, construction and burning of fuel crop residues in large scale, use of artificial instruments (like AC, fridge, vehicle). It results in ambient air pollution, noise pollution and a decrease in precipitation [1]. Air pollution leads to respiratory diseases, eye irritation, bronchitis, emphysema, and asthma, which increases individual's disease mitigation expenses and affect ones working capacity [2-3].

The Atmospheric Boundary Layer (ABL) height is an important factor that affects the vertical diffusion of atmospheric pollutants and water vapour concentrations; therefore, it impacts the formation and dissipation of air pollutants [4-8]. The continuous observation of ABL height is important with different atmosphere structure. There are many types of instruments available to observe the ABL and these instruments are divided into two categories viz. in-situ instruments and remote sensing instruments [5]. In-situ measurement is directly involved (contact) with measurement in ABL, but remote sensing measurement is used with different types of signal (like acoustic, radio wave, optical wave) [6]. These signals are transmitted into the atmosphere and received after the reflection back due to discontinuing in the atmosphere (like turbulence). SODAR is continuous remote sensing device (having Doppler Effect), robust and cheap device to monitor ABL height [4, 8], which provides different types of the atmospheric structure into their echograms [5]. The previous study has proved that ABL height based on radiosonde and LIDAR data typically deviates ± 200 m whereas radiosonde and SODAR data deviates ± 167 m [8].

The main objective of this paper is to outline some important applications of the SODAR in air pollution monitoring and as a pollution alert tool. The novelty of the present work is the application of SODAR for air quality monitoring in different hazardous conditions which are directly related to the human health problems. Qualitative effects of SODAR determined stability on the concentration of pollutants and as the concentration of the pollutants near the ground surface increase the descent of inversion base observed. Moreover, ABL height in different meteorological and hazardous situations (clear days December 22-24th 2016, foggy days December 29-31st 2016 and crop residual burning period 6-8th November 2017) of air-quality and health care system also discussed. In this respect, clear day, foggy day and crop burning day SODAR structure have been analysed, and different pollution loading conditions have been discussed.

2. MEASUREMENT AND METHODS

2.1 Study location

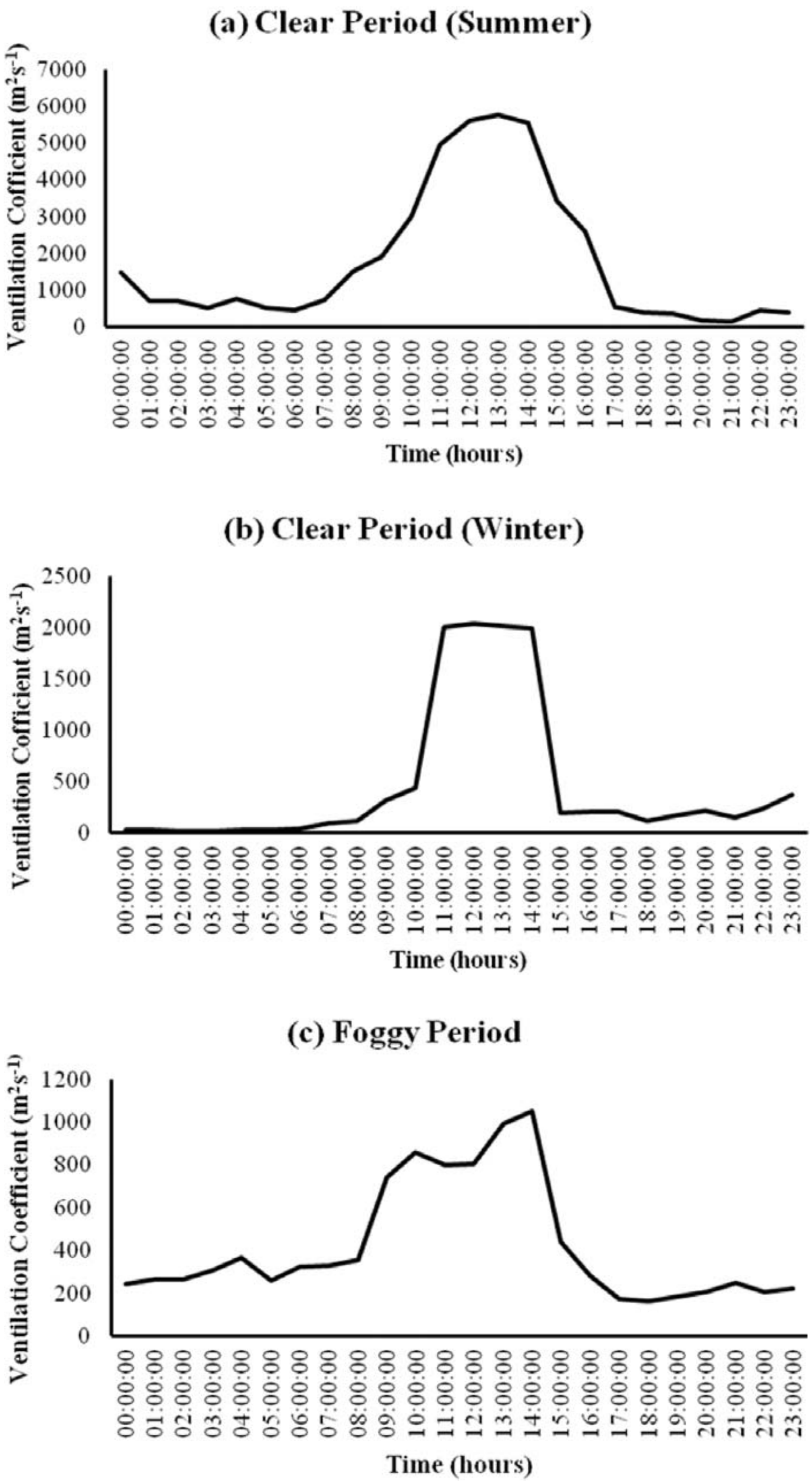
Delhi (India's capital territory) is a massive metropolitan area in the country. The location of Delhi is exactly at the intersection of 77.12° E longitude and 28.38° N latitude. The topography of Delhi can be divided into three different parts the plains, the Yamuna floodplain, and the ridge. As per the topography, Delhi is located on the western fringes of the Indo- Gangetic Plains. The climate of Delhi experiences the extremes of weather due to geological location. The climatic conditions of Delhi are similar to that of the temperate grasslands with hot, dry summers, and cold winters [5]. The summers in Delhi start from the month of April and continue until the month of July. It is very hot and dry in the summer months, with temperature soaring up to 45°C. The rainy season provides relief from the searing heat, which is frequented by Northwestern. In October the humidity levels were very high, and wind speed was low [5]. The winter months are characterised by a dip in the temperature levels often reaching around 5°C.

2.2 Measurement of ABL, meteorological parameters and pollutants

Monostatic SODAR is used for continuous monitoring of ABL. It is a well-recognised acoustic remote-sensing technique that continuously monitors ABL thermal structures up to heights in the range of 340-3400 m [5, 6]. ABL has been measured using the monostatic SODAR system, which was designed, developed and fabricated at CSIR-NPL and operated at various frequencies according to its specific requirements [7]. The Monostatic SODAR is operated at a frequency of 2.25 kHz with 50-350 ms (selectable) pulse duration, a cycle time of 2-20 s (selectable) and electrical transmitting power up to 50 watts and an acoustic power of 10 watts [5]. The SODAR antenna is a parabolic dish 1.22 m in diameter and the beam width is 15°. SODAR echograms are reflex images of the turbulence in the lower atmosphere. This turbulence is accountable for the dispersion of pollutants. One year complete SODAR dataset from December 2016 - November 2017 has been used in this study. The meteorological and concentrations of pollutants data were taken from the online website, which is maintained by central pollution control board [9-10].

3. SODAR APPLICATION IN DETERMINING THE POLLUTION LOADING CAPACITY OF THE REGION

The product of ABL (mixing height) measured by SODAR and the average wind speed is called Ventilation Coefficient (VC), it is an atmospheric condition which indicates the air quality and pollution potential, *i.e.*, the capability of the atmosphere to dilute and disperse the pollutants over an area. The higher value of the ventilation coefficient, the more efficiently the atmosphere can dispose of the pollutants and thus the air is better quality. In contrast, lower value of ventilation coefficients leads to poor dispersal of pollutants causing stagnation and poor air quality leading to possible pollution related hazards. The ventilation coefficient is directly related to the ABL height and the average wind speed through the mixing layer. A variation in the values of the ABL and the average wind speed causes a change in the ventilation coefficient. Ventilation coefficient less than 6000 m^2s^{-1} during afternoon hours indicate high


(a) Clear Period (Summer)
Ventilation Cofficient (m^2s^{-1})
7000
6000
5000
4000
3000
2000
1000
0
00:00:00
01:00:00
02:00:00
03:00:00
04:00:00
05:00:00
06:00:00
07:00:00
08:00:00
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23:00:00
Time (hours)
(b) Clear Period (Winter)
Ventilation Cofficient (m^2s^{-1})
2500
2000
1500
1000
500
0
Time (hours)
(c) Foggy Period
Ventilation Coefficient (m^2s^{-1})
1200
1000
800
600
400
200
0
Time (hours)

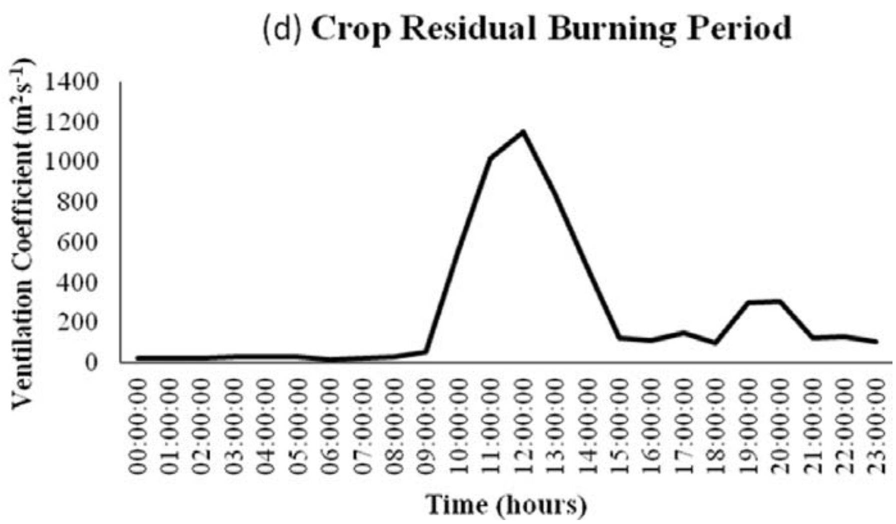

Fig. 1 Temporal variation of Ventilation Coefficient in different weather condition

pollution potential, or during morning hours ABL height less than 500 m is the criteria for the occurrence of high pollution potential [11]. Using SODAR data Ventilation coefficient has been calculated over Delhi, which shows severe pollution loading. Figure 1 represents the temporal variation of ventilation coefficient in the clear period (summer, winter), foggy period and crop residual burning period condition. A higher value of ventilation coefficient has been observed during the daytime and lower in the nighttime, *i.e.* the pollution loading capacity of the atmosphere is good during daytime and poor in the night time.

4. DETERMINATION OF ATMOSPHERIC STABILITY

Atmospheric stability is one of the critical parameters for the air pollutants [4, 6]. Many kinds of literature defined the atmospheric stability with a different meteorological parameter, but Pasquill proposed six

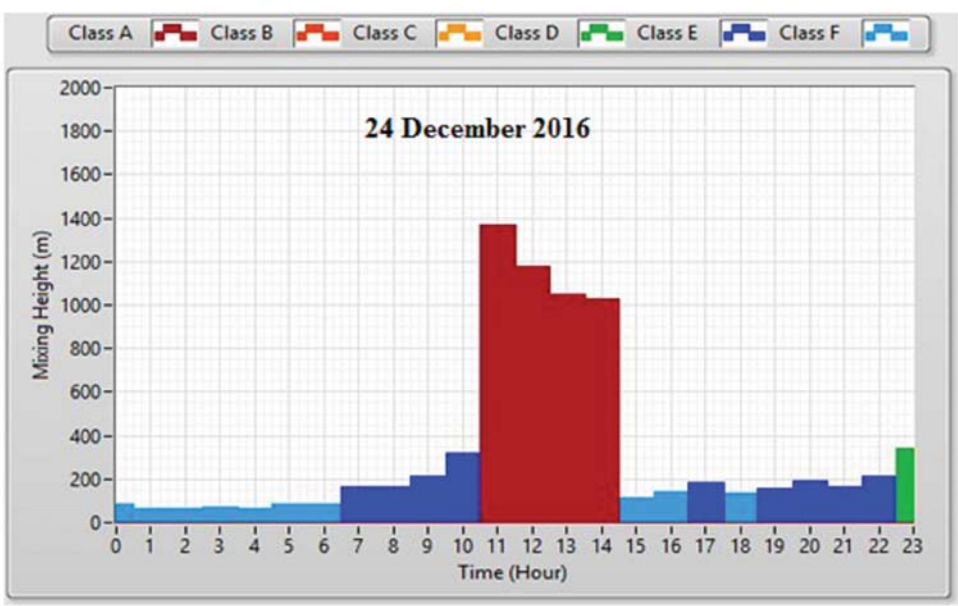

Fig. 2 Temporal variation of Stability Class

simple stability class based on turbulence and wind speed [6] and Singal presented these class based on ABL height (SODAR Echograms) [5, 6]. These classes were Class A (very unstable), Class B (moderate unstable), Class C (slightly class), Class D (neutral class), Class E (slightly stable) and Class F (very stable). The atmospheric stability class have been used to study the dispersion and diffusion of pollutants. The unstable state is an indicator of good ventilation, and stable state is indicator of poor ventilation [4-6]. The class A is the best to condition, and class F is the worst condition for dispersion and diffusion of pollutants [5, 6]. The daily average of ABL was low in post-monsoon and high in pre-monsoon, because in the pre-monsoon season temperature and wind speed was high and humidity was low, and in post-monsoon season humidity is high [5-7, 12]. Therefore, the concentration of pollutants increased in post-monsoon season. Based on above discussion on SODAR capabilities, SODAR is a virtuous useful system for air quality applications. Figure 2 represents the temporal variation of stability class and ABL height in the clear weather condition. It has observed that daytime dominates class A (*i.e.* unstable condition) and class E and class F (*i.e.* stable condition) is dominated in the night time.

5. SODAR APPLICATION IN AIR-POLLUTION WARNING SYSTEM

Figure 3 represents the scheme of the decision algorithm for air-pollution alarms in different atmospheric conditions. The synoptic analysis and actual observation of ABL height by SODAR have been used to calculate several kinds of information and verification of stability of actual pollution conditions.

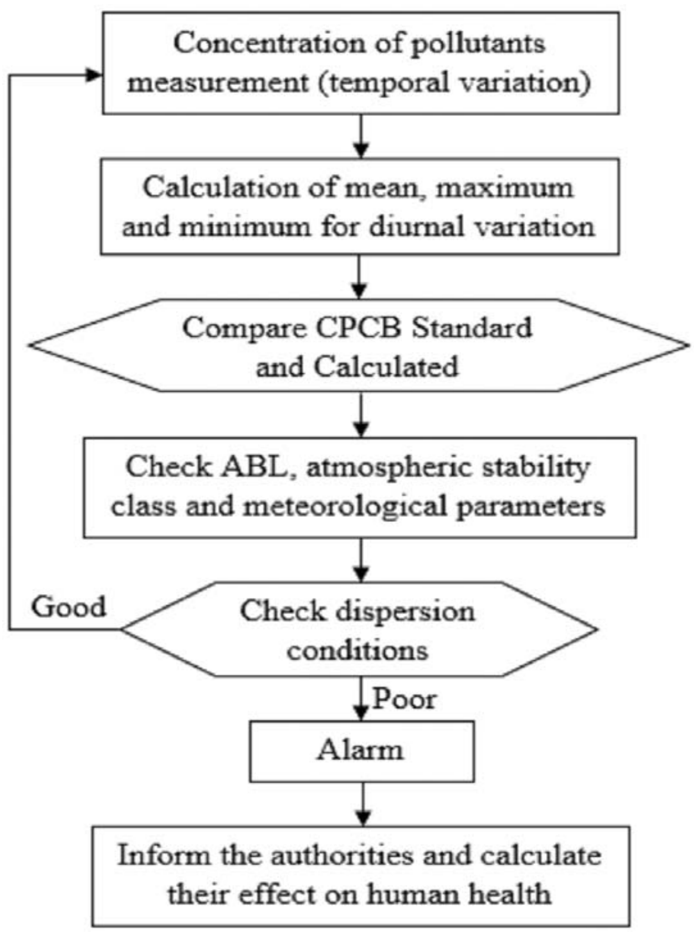

Fig. 3 Scheme of the decision algorithm for air-pollution in different condition

6. SODAR STRUCTURE IN VARIOUS CONDITIONS

Figure 4 (a, b and c) represent the echograms of clear days, foggy days and crop residual burning period in the inversion condition. The inversion condition has a characteristic feature of the night-time stable conditions, dissipates in the morning after sunrise due to solar heating of the ground and the temperature profile changes its shape [5-6]. Table 1 shows the daily average of ABL, meteorological parameters and concentration of pollutants in different conditions. Positive correlation (0.699, 0.607) has been observed between ABL with temperature and wind speed and similarly negative correlation (-0.558) has been found with relative humidity. Also, negative correlation (-0.213) has been found between concentrations of $PM_{2.5}$ and ABL. The high concentration of pollutants (SO_2, NO_2 and $PM_{2.5}$) has been observed in the crop residual burning days.

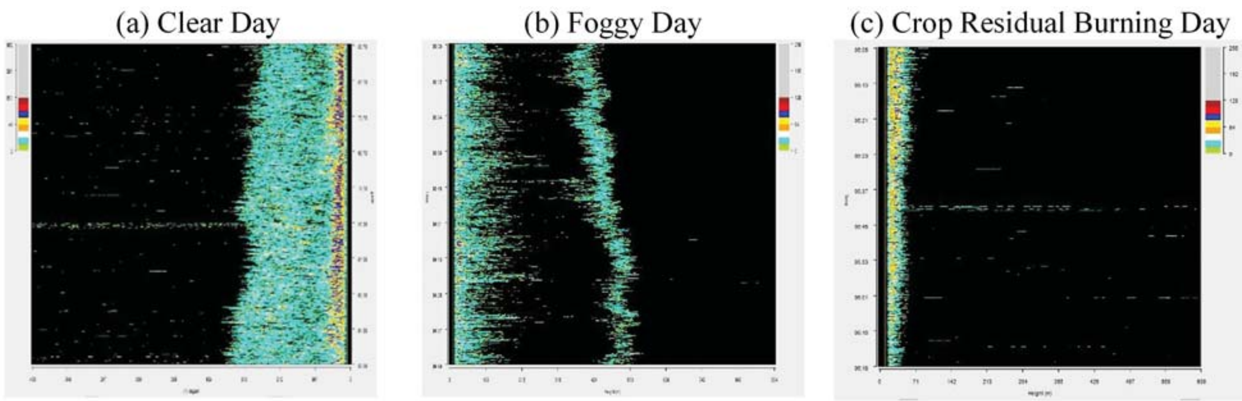

Fig. 4 Inversion condition

Figure 4 (a) shows clear day inversion condition echograms, which has been observed during night time in the winter season. It is more frequent in the month of December and January. The daily average value of ABL and VC have been found 319±393 m and 330±208 m^2/s respectively, because of average high wind speed (1.032±0.53 m/s) and temperature (17.450±3.53°C) and average low relative humidity (77.80±19.99%). High standard deviation (±393) in ABL has been observed in clear days. In clear days, class E (43.83%) is dominated by nocturnal condition, and convective condition dominates class A (16.67%).

Figure 4 (b) represents the foggy day condition, which has been observed during the winter season, but it is not common in all periods of winter. It has generally formed between the middle of December to the middle of January. The daily average of ABL and VC have been found 285±150 m and 440±40 m^2/s respectively, because of high relative humidity (90.02±11.62%) and low temperature (14.48±2.33°C). Low standard deviation (±150) in ABL has been observed on foggy days. The class E (66.67 %) is dominated in inversion periods, and class C (25%) is dominated in convective periods. The ratio of $PM_{2.5}$/ABL, SO_2/ABL and NO_2/ABL is shown in Table 2. The lowest value of the ratio is observed in foggy days due to fog formation and more stable condition. As a result, poor visibility has been observed on foggy days.

Figure 4 (c) represent the agriculture crop residual burning day echograms, which has been observed during post-monsoon months, i.e., middle of October to start of November. The daily average of ABL and VC have been found 308±366 m and 198 ± 111 m^2/s respectively, because of high relative humidity (90.02 ± 11.62 %), low wind speed (14.48 ± 2.33 $m.s^{-2}$) and less change in wind direction. The class F (41.67%) has been dominated in nocturnal condition, and class A (12.5 %) has been dominated in convective condition. It has found that the standard deviation has been exceeded the average ABL values during different meteorological conditions as during afternoon time highest value (for the short-time period) of ABL height is observed in all conditions and almost stable ABL height is found in the evening, night and early morning (long-time period). Histogram of the ABL in different meteorological condition is presented

Table 1. Average Daily value of ABL, Meteorological data and concentration of pollutants at Delhi.

	ABL (m)	Wind Speed (m/s)	Tempera-ture (°C)	Relative Humidity (%)	Ventilation coefficient (m^2/s)	SO_2 ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	NO ($\mu g/m^3$)	NO_x ($\mu g/m^3$)	CO ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)
Crop Residual Burning Period (6-8th November 2017)											
Average	308.54	0.642	25.95	70.67	198	15.432	70.98	46.61	72.62	1.898	556.64
Standard Deviation	366.39	0.303	3.37	27.04	111	11.21	22.61	33.21	29.41	0.803	138.59
Maximum	1305	1.43	31.83	96.45	1866	46.85	122.5	131.24	133.36	3.32	747.3
Minimum	55	0.36	22.11	24.01	20	2.2	41.24	12.48	29.94	0.42	246.88
Clear Period (December 22-24th 2016)											
Average	319.17	1.032	17.45	77.80	330	9.5013	29.08	89.01	92.00	2.397	260.13
Standard Deviation	393.76	0.528	3.52	19.98	208	7.624	11.58	98.36	78.96	1.516	47.453
Maximum	1370	1.93	22.7	98.99	2644	29.07	72.88	262.06	230.04	5.41	324.34
Minimum	65	0.35	12.58	43.41	23	2.1	17.96	7.52	20.98	0.13	165.42
Foggy Period (December 29-31st 2016)											
Average	285.21	1.405	14.48	90.02	400	8.229	23.79	16.38	30.92	0.929	133.90
Standard Deviation	150.76	0.260	2.33	11.62	40	6.082	3.23	10.83	9.46	0.320	24.87
Maximum	610	1.87	18.38	98.95	1140	23.45	29.49	40.84	50.65	1.67	177.52
Minimum	135	0.93	11.8	66.27	125	1.6	18.66	7.46	21.1	0.53	86.56

Table 1. Ratio between ABL and SO_2, NO_2 and $PM_{2.5}$

	SO_2/ABL (µg/m^4)	NO_2/ABL (µg/m^4)	$PM_{2.5}$/ABL (µg/m^4)
Crop residual Burning Period	0.050	0.227	1.80
Clear Period	0.029	0.091	0.810
Foggy Period	0.028	0.083	0.466

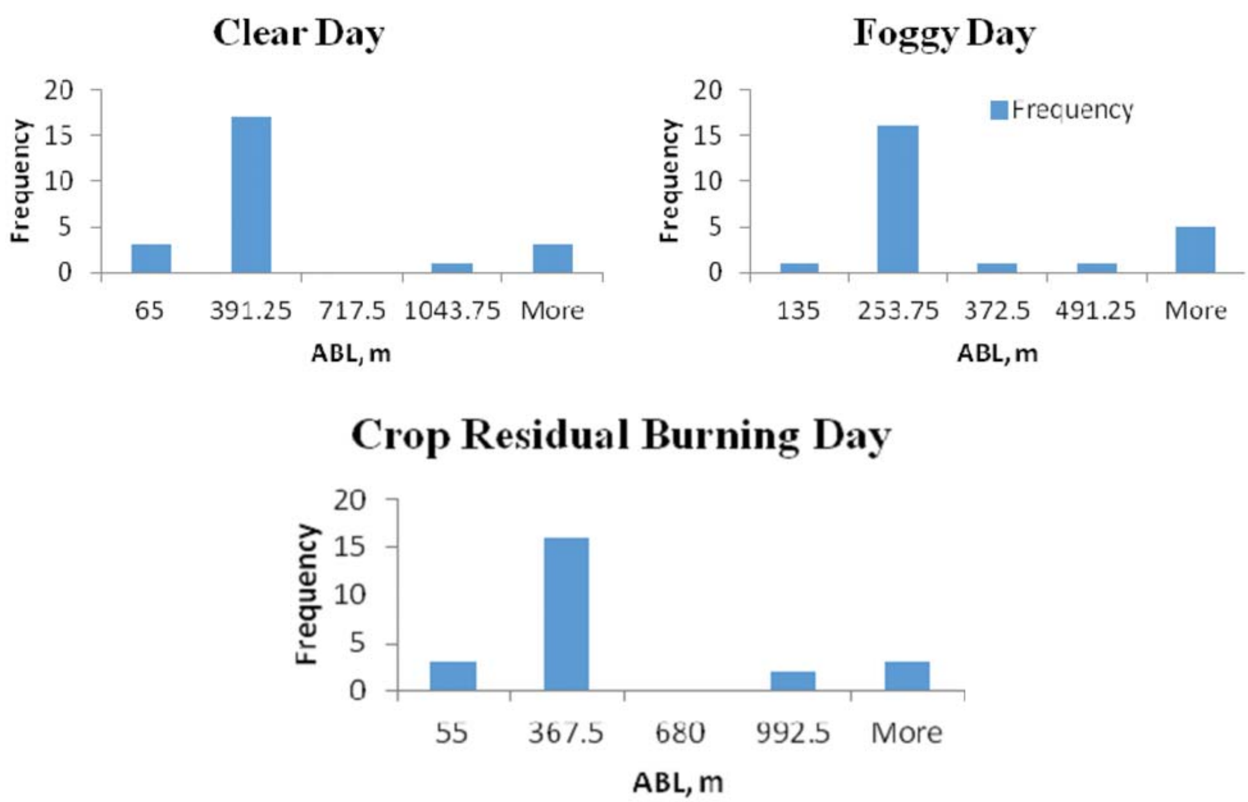

Fig. 5 Histogram of ABL during different meteorological condition

in figure 5. From figure large variation in the ABL values and their number of frequency have been observed. It has observed that ratio between pollutants and ABL is higher in crop residual burning period. It has indicated that ratio and stability class in the nocturnal condition of the crop residual burning days have relatively more critical periods for dispersion of pollutants. Based on the above-compared results, it showed alarming condition for dispersion of pollutants during different meteorological conditions. It is clear from the Table 1 that during the crop residue burning day's level of pollutants goes up to 2-2.5 time higher than the clear days and approx. 3-3.5 time higher than the foggy days. This can cause poor visibility, respiratory diseases, eye irritation, and asthma [2-3, 12-17]. The pollutants have entered into the human body by directly or indirectly way (like respiration, eating, drinking *etc.*) and it has mixed with blood then impelled into all body [18].

6. CONCLUSION

It has been observed that SODAR is an important tool for the air pollution monitoring. Real-time monitoring of ABL using SODAR is essential for the air quality management. Continuous high-resolution observations of ABL are required to understand of pollutants dispersion in the atmosphere. Based on the comparison of ABL, meteorological data and pollutants, it is observed that dispersion of pollutants depends on the ABL and meteorological data. The concentration of pollutants were high in crop residual burning days. The standard deviation of ABL, meteorological data, and concentration of pollutants have been observed low during foggy days. The above results provided reliable basic data for better portraying the structure of ABL and concentration of pollutants and improving the parameterisations of the ABL in meteorological models. Studies of the ABL and its characteristics at different days of pollution reveal the thoughtful meteorological factors for the formation, evolution, and dissipation of heavy pollution.

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Therapeutic impact of Hindustani ragas on the mood of patients with cerebrovascular accident and diffuse head injury

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ABSTRACT

This paper is focused on investigating the therapeutic impact of Hindustani ragas on level of depression in the Cerebrovascular Accident (CVA) and Diffuse Head Injury (DHI) Patients. A randomized control trial was conducted. The case group consisted of 30 patients who received both medicine and Hindustani ragas, while the control group of 30 patients received only medicine. A total of 10 Hindustani ragas were taken up, and 4 follow-ups with baseline were conducted. Beck Depression Inventory (BDI) is used to assess the level of severity of depression of the sixty patients in different time intervals. Linear Regression analysis showed the BDI scores of music group patients to be 0.013, 3.53, 6.41, and 4.53 times lower than those of the control group when duly adjusted for the effect of other independent variables viz. sex, age and education in the equation.

1. INTRODUCTION

Functional Magnetic Resonance Imaging studies suggest that several distinct brain areas are involved in the processing and appreciation of music. It is believed that some hindustani ragas control the cruel behavior of animals as well, not to speak of humans. Modern science and discoveries indicate that music has healing powers particularly in relieving psychological diseases and negative emotions. In India, legend has it that Thyagaraja, the famous musician of South India, brought a person, who was declared dead, back to life by singing the composition Naa Jeevan Dhara in raga Bilahari (Rammohan, 2009). In 1729, Richard Browne, a physician wrote the famous text Medicina Musica which describes the use of music as medicine. Dr. Burnell has mentioned a manuscript named Raga Chikistsa in the collections of Saraswati Mahal Library in Tanjore which deals with the various ragas that can be used for curing various ailments (Source: http://www.indiaprofile.com/ayurveda/musictherapy.htm).

2. LITERATURE REVIEW

Music Therapy has a positive effect on mood in post-stroke patients and may be beneficial for mood improvement with stroke (Kim, Park, Choi, Im *et al.*, 2011). Music therapy is found to affect physiological phenomena such as blood pressure, heartbeat and respiration, as well as emotional aspects such as mood and feelings (Standley, 1986). Clinical studies in adults also demonstrated correlations between the physiological and emotional stimulation effects of music (Peretti and Zweifel , 1983). Clair and Bright showed significance of music on the reduction of depression and anxiety induced in strokes patients during recovery (as cited in Kim *et al.*, 2011).

Prevalence of post-stroke depression is significantly high (32.9-35.9%) as compared to the prevalence of depression in general population (10%) (Robinson, 2003; Kessler *et al.*, 1994). Kim *et al.* (2011) demonstrated that music therapy can reduce depressed mood or have positive effects on mood in post-stroke patients. Bradt *et al.* (2010) stated that music therapy has power to stimulate brain functions involved in emotion, cognition, speech and sensory perception used in rehabilitation phase.

Music listening can be used to relax, improve mood, and provide both physical and mental activation during the early stages of recovery from stroke. Thus, music listening could provide a useful clinical tool in stroke rehabilitation (Forsblom *et al.*, 2009). Sarkamo *et al.* (2008) demonstrated that music listening during the early post-stroke stage can enhance cognitive recovery and prevent negative mood. Mossler *et al.* (2011) searched the Cochrane Schizophrenia Group Trials Register (December, 2010) and supplemented this by contacting the authors of relevant study, hand searching of music therapy journals and manual searches of reference lists and suggested that music therapy improves global state and may also improve mental state and functioning if a sufficient number of music therapy sessions are provided. Sunder, Sumathy (2007) concluded that Indian music therapy is an integration of ancient healing practices and musical traditions coupled with the recent modifications, derived from the modern day practice and the knowledge gained by current clinical studies undertaken. Kim *et al.*, (2011) concluded that the Music therapy has a positive effect on mood in post-stroke patients and may be beneficial for mood improvement with stroke and they also found that Beck Anxiety Inventory (BAI) and Beck Depression Inventory (BDI) scores showed a greater decrease in the music group than the control group after music therapy, but only the decrease of BDI scores were statistically significant ($p=0.048$).

Singh *et al.* (2013) concluded that improvement in visual acuity, spatial orientation, and cognitive functions involving both right and left hemispheres is faster in the music group with follow-ups than that in the control group

According to Buffum M.D. *et al.* (2006), music therapy could reduce anxiety in patients undergoing angiography. Moreover it has been established that music therapy reduced anxiety in patients who received mechanical ventilation respiration (Lee, Chung, Chan M.F., and Chan W.F., 2005).

3. OBJECTIVE

To investigate the therapeutic impact of Hindustani ragas on level of mood depression in the Cerebrovascular Accident (CVA) and Diffuse Head Injury (DHI) Patients

4. MATERIALS AND METHODS

A randomized control trial was conducted to assess the impact of Hindustani ragas in patients with CVA and DHI, during the rehabilitation phase, at RIMS, Ranchi, in collaboration with the Birla Institute of Technology (BIT), Mesra, Ranchi, India. A total of 60 patients 18 years of age or older, were recruited for this study. Rapport was established, and written informed consent was obtained from the patients or the head of his or her family. Baseline data were collected from all 60 patients. A case group (hereafter referred to as music group) of 30 patients were those to whom both medicine and prerecorded Hindustani

Table 1. Ragas and their time of rendition.

S.No.	Ragas administered to patients	Time of Rendition
01	Bhairav	5 AM to 8AM
02	Ahir Bhairav	5 AM to 8AM
03	Bilaval	6 AM to 9 AM
04	Todi	9 AM to 12AM
05	Bhimpalashree	1 PM to 3 PM
06	Pilu	1 PM to 3 PM
07	Multani	3PM to 6PM
08	Yaman	6 PM to 9 PM
09	Bhairavi	6 PM to 9 PM
10	Bageshree	9 PM to 12 PM

ragas were administered, while the control group of 30 patients received medicine only. Ten Hindustani ragas were selected for the music group patients as detailed in Table 1, along with their suitable time of rendition. The intervention began on an average after 15 days only when the Glasgow Coma scale (GCS) score was recorded to be greater than 8, indicating that the patient was out of the life-threatening phase.

4.1 Inclusion Criteria

For the recruitment of the patients as a study subjects the following four inclusion criteria were adopted:

i. patients suffering from CVA/DHI
ii. > 18 years of age.
iii. Glasgow Coma Scale(GCS) : 9-12
iv. Patients partially rehabilitated with no residual impairment of auditory and cognitive response.

4.2 Exclusion Criteria

Similarly, the following two criteria were adopted for excluding the patients as study subjects

i. Auditory impairment patients are excluded.
ii. Those suffering from concomitant acute illnesses

4.3 Intervention of Music Therapy

The patients in the music group were subjected to both medicine and music therapy (Hindustani ragas), while the patients in the control group were given medicine only. A prerecorded cassette and a cassette player along with a headset were used for listening to ragas. All cassettes, cassette players, and headsets used by the patients in the music group were identical and of the same company. The patients were subjected to each of the previously mentioned ragas for a duration of 20 minutes every day, for up to 6 months (total of 3 hours 20 minutes each day for all the 10 ragas), per their convenience but within the time of day as mentioned in Table 1.

While listening to the ragas, the patients were instructed to follow certain steps as listed here:

1. closing their eyes;
2. focusing on the breathing process by placing their hands on the abdomen; and
3. listening to the raga intently.

For the patients who were unfamiliar with ragas, some songs based on a particular raga (even songs from movies) were played first before the raga itself. The idea is to get the patient acclimatized to the raga mood by listening to something familiar and related. Here selecting a movie song randomly will not help as the song has to be related to the raga. Although one of the researchers knows classical music and could easily do the song selection, we took the services of a DMus (vocal) artist (from Banaras Hindu

University) who is not related to our research, in an attempt to reduce the researcher's bias. Further, the song to be used for a specific patient was selected by lottery from the list of songs. For example, the songs Chingari koi bhadke" sung by Kishore Kumar in the Bollywood movie Amar Prem and the song "Jyot se jyot jagate chalo" sung by Mukesh in another Bollywood movie Sant Gyaneshwar, both based on the raga Bhairavi, were in the list. But we decided by lottery which patient would listen to which of the 2 songs. The patients were given liberty to adjust the music sound (volume, *etc*) per their liking. They were also encouraged to use their vocal cords through gentle murmurs. The patients in both the music group and the control group were observed, and the patients in the music group were helped to listen to the ragas directly during their stay in the hospital. Before discharge, the patients were again trained regarding the specific period of the day for listening to specific raga, duration of listening to each raga, and proper way of listening to each raga as mentioned earlier, so that they would follow the listening protocol at home. The patients in the music group were subjected to each of the 10 ragas for a duration of 20 minutes only every day within the previously mentioned time of the day per their convenience, for a duration of 6 months. The choice of 20 minutes although subjective was necessitated primarily due to 2 factors: (1) the duration should not be too short as the raga atmosphere takes some time to build, and (2) the duration should not be too long either that it becomes taxing for the patients.

4.4 Tool and Technique Used for Data Collection

Beck Depression Inventory (BDI) : It is a 21-question multiple-choice self-report inventory. Each question has a set of at least four possible answer choices, ranging in intensity. Its development marked a shift among health care professionals, who had until then viewed depression from a psychodynamic perspective, instead of it being rooted in the patient's own thoughts. When the test is scored, a value of 0 to 3 is assigned for each answer and then the total score is compared to a key to determine the depression's severity. Each question has a set of at least four possible answer choices, ranging in intensity. For example :

(0) I do not feel sad.

(1) I feel sad.

(2) I am sad all the time and I can't snap out of it.

(3) I am so sad or unhappy that I can't stand it.

When the test is scored, a value of 0 to 3 is assigned for each answer and then the total score is compared to a key to determine the depression's severity. The cut off scores are as follows :

- 0-9 : indicates minimal depression
- 10-18 : indicates mild depression
- 19-29 : indicates moderate depression
- 30-63 : indicates severe depression

Higher total scores indicate more severe depressive symptoms

4.5 Plan for Data Collection

Using the aforementioned tool, the patients in both the music and the control groups were assessed as shown in the flowchart (Figure 1).

5. EXPERIMENTAL RESULTS

A total of 60 patients were studied. Mean age was 55.2 yrs with standard deviation (SD) 17.7 yrs for music group and the same was 55.8 yrs with SD 12.5 yrs for control group patients. Twenty one out of thirty (70%) patients were male in music group whereas sixteen out of thirty (53.3%) patients were male in control group. There were no significant differences in age and sex between the two groups. In the educational status of patients, it was found that majority of patients were 5th standard (primary education) in both groups.

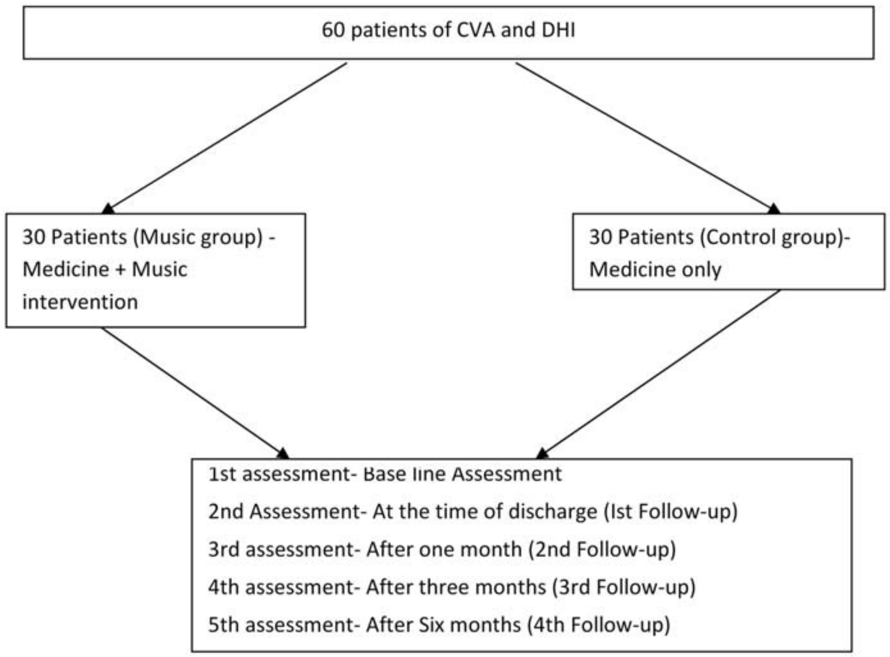

Fig. 1 Flow Chart for method of data collection

Table 2. Mean (SD) score of BDI of the patients in control and music groups in different follow-ups.

Different visits	Music Group (N=30)	Control Group (N=30)	t value	Degree of freedom	P value
Baseline	38.33(3.45)	38.73(3.41)	0.452	58	0.653
1st Follow-up	37.47(3.29)	37.77(3.45)	-0.345	58	0.732
2nd Follow-up	27.87(2.74)	31.40(2.69)	-5.045	58	0.000
3rd Follow-up	15.77(2.53)	22.30(2.43)	-10.218	58	0.000
4th Follow-up	7.10(1.67)	11.53(2.71)	-7.624	58	0.000

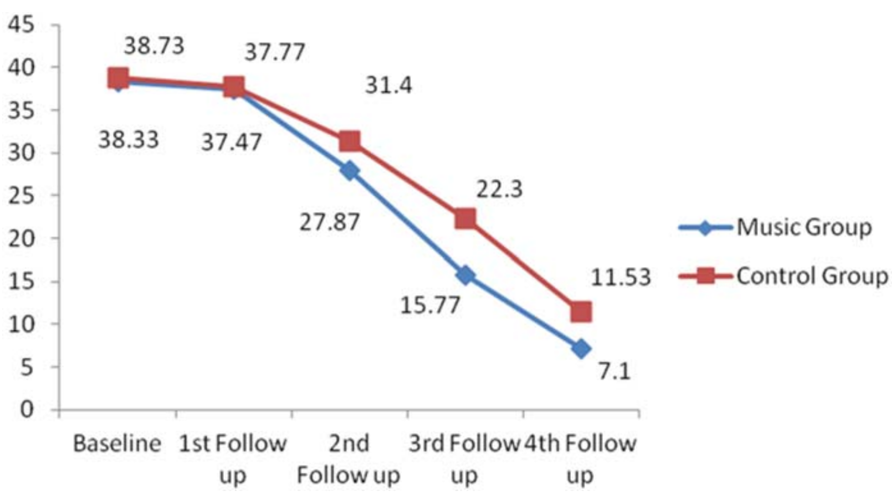

Fig. 2 Mean BDI score of the patients in different follow ups

The mean BDI of the music group before music therapy was 38.33 with SD 3.45 and that of the control group was 38.73 with SD 3.41. There was no statistical difference between the two groups (t= 0.452, df=58, P=0.653). This mean score after music therapy was decreased by 31.23 whereas in control group decreased by 27.2. The mean BDI were found to be greater decreased in music group than the controls group in 3rd and 4th Follow-ups (fig. 2). There was also statistically significant in 2nd, 3rd and 4th Follow-ups between the groups.

Table 2 gives a picture of percentage of the patients belonging to different level of depression on the basis of total BDI scores in music and control groups in different follow-ups. In 4th follow up, 96.7% of the music groups' patient reached normal level of depression whereas only 26.7% of control groups' patient reached normal level of depression.

Table 3. Percentage of the patients according to different level of depression on the basis of total BDI scores in music and control groups in different follow-ups.

Different Visits	Depression level	Music Group (N=30)	Control Group (N=30)
Baseline	Severe (30-63)	30(100%)	30(100%)
1st Follow-up	Severe (30-63)	30(100%)	30(100%)
2nd Follow-up	Moderate (19-29)	26(86.7%)	6(20.0%)
	Severe (30-63)	4(13.3%)	24(80.0%)
3rd Follow-up	Mild (10-18)	25(83.3%)	2(6.7%)
	Moderate (19-29)	5 (16.7%)	28(93.3%)
4th Follow-up	Normal (0-9)	29(96.7%)	8(26.7%)
	Mild (10-18)	01(3.3%)	22(73.3%)

6. DISCUSSION

The decrease in mean BDI score in the 2nd, 3rd and 4th Follow-ups were found to be significant between the two groups (table1). In particular, this decrease in the music group was rather high in 3rd and 4th Follow-ups as compared to that in the control group.

However, on the basis of standardized categorization of the BDI scores it was found that in 4th follow up, 96.7% of the music group patients reached minimal depression *i.e.*, normal level (<= 9) of depression whereas only 26.7% of control group patients reached normal level of depression (Table 2).

Further, by using linear regression, in the 1st, 2nd, 3rd and 4th follow ups, corresponding BDI score of music groups patients is .013, 3.53, 6.41, and 4.53 times lower respectively than the control group when duly adjusted for the effect of other independent variable *viz.* sex, age and education in the equation. This is significant also in 2nd, 3rd and 4th follow ups (table 3).

The above findings are consistent with the study finding of Kim *et al.* (2011), who concluded that Music therapy has a positive effect on mood in post-stroke patients and may be beneficial for mood improvement with stroke. The Beck Anxiety Inventory (BAI) and Beck Depression Inventory (BDI) scores showed a greater decrease in the music group than the control group after music therapy, where only the decrease of BDI scores were statistically significant (p=0.048). This is in conformity with the present study in which BDI score significantly decreased in music group patients.

Similarly, Forsblom A. *et al.*, (2009) have noticed that music listening can be used to relax, improve mood and provide both physical and mental activation during the early stages of recovery from stroke. Magee WL *et al.*, (2002) have also concluded that music therapy is an effective intervention to address negative mood states in neuro-rehabilitation population.

Our study findings are also consistent with the findings of the study by Jun E.M. *et al.*, (2013), who concluded that music and movement therapy improved their mood state and increased their shoulder and elbow joint flexion. Thaut M.H. *et al.*, (2009) have also found, in the music therapy group, significant improvement in executive function and overall emotional adjustment, apart from lessening of depression, sensation seeking and anxiety.

7. CONCLUSION

The mean BDI were found to be greater decreased in music group than the controls group in 3rd and 4th Follow-ups. 96.7% of the music groups' patient reached normal level of depression whereas only 26.7% of control groups' patient reached normal level of depression. This finding concludes that Hindustani ragas as a therapeutic tool may act as a catalyst in improving level of mood depression in patients with CVA and DHI. However, further studies are required in this field, for example, comparing the relative therapeutic impacts of classical and light music. It is also important to note the following:-

(i) Therapeutic benefits of the music also depends upon understanding of language. Western music may not give the benefits to Indian people and vice versa. This study attempts to measure the benefit of Indian music to Indian people. A second reason is that ragas are very rich in their melodic content and music rich in rhythm but poor in melody may excite the sympathetic nervous system causing more harm than good.

(ii) In the research team, three medical faculties were mainly involved in observing the mood of the patients who also administered the Mini mental state examination (MMSE) and PGI Brain dysfunction scale. These tools evaluated the mental status as well as brain functions.

(iii) The ragas were selected to cover morning, afternoon, evening and night in order to have optimum effects because it has been observed that ragas generate feelings which match with the feelings we experience during a particular time of the day (a raga of the Bhairav group like Ahir Bhairav matches with the feeling of waking up from sleep in the morning).

8. DISCLOSURE

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2. **Author contributions :** Shashi Bhushan Singh, MSc (Statistics), PhD in Science, currently an Associate Professor and statistician in the Department of Preventive and Social Medicine, Rajendra Institute of Medical Sciences, Ranchi contributed in the interaction with the patients and statistical analysis in the study.

   Soubhik Chakraborty, M.Sc.(Statistics), PhD in Science (Statistics), currently a Professor in the Department of Mathematics, Birla Institute of Technology, Mesra, Ranchi contributed by providing expert statistical opinion and views related to music as well as review and designing of the paper.

   Keashav Mohan Jha, MCh (Neuro-Surgery), an Additional Professor in the department of Neuro-Surgery at Indira Gandhi Institute of Medical Sciences, Patna who initially served in the Neuro-Surgery department of Rajendra Institute of Medical Sciences, Ranchi when this study was undertaken (before his recent transfer to IGIMS Patna) contributed by providing patients' selection, diagnosis and treatment, thereby offering expert neurosurgical and neuro-musicological opinion in the study.

Satish Chandra, MD (Pharmacology), currently a Professor in the department of Pharmacology, Rajendra Institute of Medical Sciences, Ranchi, contributed in the rehabilitation part and follow-ups of the patients and providing medical opinion in the work.

Shanti Prakash, MD (Anesthesiology), currently an Associate Professor in the department of Anesthesiology, Rajendra Institute of Medical Sciences, Ranchi, contributed in both treatment (intensive care) and rehabilitation as well as giving an overall opinion from the medical side.

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Evaluation of differences between international speech test signal (ISTS), Kannada passage english passage and other non-speech stimuli

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ABSTRACT

The present study aimed to measure and compare the sound pressure level (SPL) obtained across different stimuli (ISTS, Kannada passage, English passage, pure tone sweep and Digital speech). Material and method: A total of 30 individuals were included in the study. The stimuli used include a frequency swept sine wave, ANSI (American National Standard Institute) weighted and ICRA (International Collegium of Rehabilitative Audiologists) weighted digital speech, ISTS (International Speech Test Signal), recorded passages in Kannada and English language. The real ear SPL at the ear canal was obtained at octaves and mid octaves from 250 Hz to 8000 Hz. The test retest reliability was assessed by repeating the experiment after a week. Results: The results revealed that the SPL of ISTS was significantly different than that obtained for the Kannada and English passages. Further, these differences were more at low and mid frequencies than high frequencies. Both ICRA and ANSI weighted digital speech stimuli were similar to the recorded passages in most of the frequencies. In addition, the results showed high test retest reliability. Conclusion: The use of ISTS for testing and evaluation of hearing aids in the context of Kannada and Indian English should be done with caution.

1. INTRODUCTION

Nonlinear hearing aids digitize, amplify the less intense sounds and compresses the high intense sounds of the incoming acoustic signal. Performances of nonlinear hearing aids are evaluated in real ear analyzers using standard stimuli. Comparing the performance of hearing aids with the stationary stimuli like sine wave frequency sweeps and unmodulated noise[1, 2] are not effective as tonal stimulus are not encountered by hearing aid users in their daily life. Hence, for the electro acoustic measurements, the tonal stimulus was replaced with the composite signal. The composite signal is a combination of several tonal signals. However, these stimuli lack the temporal fluctuations and the gaps that are present in real speech. To overcome these limitations, the composite signal was replaced by digital speech stimuli. Digital speech stimuli are modulated signals having modulations of about four times per second to approximate the temporal patterns of speech[3].

The development of composite signal and digital speech signal were one step towards achieving the generalization of results to real speech. The gain or the output of the hearing aid could be well determined with speech or speech-shaped stimuli[4, 5, 6]. Hence, it is essential to develop standardized speech stimuli for hearing aid testing and evaluation across the globe.

The digital speech stimuli have some characteristics which are similar to speech. Nevertheless, they lack the co- modulation characteristics of speech. Hence, International Speech Test Signal (ISTS) was developed by the European Hearing Instrument Manufacturers Association (EHIMA)[7]. It is developed considering the features of six major languages spoken in a female voice. The ISTS contains pauses and modulation characteristics like that of natural speech and has a dynamic range of 20-30 dB[7]. The speech stimulus used for hearing aid verification has been reported to have a similar spectrum to that of the International Long- Term Average Spectrum (ILTASS)[8, 9]. The ISTS resembles the ILTASS within 1 dB.

The ISTS is a standardized stimulus used for quantifying the frequency responses of the hearing aid [7, [9, 10, 11]. It is incorporated in the recent real ear analyzers for insertion gain measurements as a part of hearing aid testing and evaluation. The main aim of the hearing aid testing and evaluation is to ensure good audibility of speech and good speech intelligibility. The objective of testing and evaluation of hearing aids is to ensure that the lab verified settings lead to real life improvements in speech intelligibility.

It is important to use a stimulus that is similar to natural speech. ISTS has been reported to exhibit a minimal difference of less than 2 dB when compared with the Brazilian Portuguese language[12]. Kannada is the official language of Karnataka, a state in South India. The majority of service seekers at the All India Institute of Speech and Hearing (AIISH) which is situated in Karnataka speak Kannada. The Kannada language has more occurrences of long vowels. The occurrence of phonemes differs in Kannada language when compared to English and other Western languages. These are the factors responsible for LTASS of Kannada language being different from the other languages[13].

Hence, there is a need to compare the ISTS and other standardized stimuli (available for insertion gain measurements) with natural speech to ensure that the real ear SPL of natural speech of the local language is not different from these standardized stimuli. Kannada has also been reported to have more energy at the low frequencies than when compared to high frequencies and it has differences when compared to English and other Western languages[13]. The spectrum of Kannada has also been reported to be different from other Western languages and the International Long Term Average Spectrum[14]. These differences between Kannada and other languages, and the exclusion of the Indian language in the ISTS mandates the need to compare the SPL of Kannada with that of ISTS. This comparison would direct us in choosing the correct stimuli for objective hearing aid evaluation and thus, in generalizing the results of the same to real life situation. Hence, the objectives of this study were to compare the SPL of the Kannada and Indian English with that of ISTS and other standard non speech stimuli that are regularly used in insertion gain measurements.

2. METHOD

The stimuli used includes a frequency swept sine wave, digital speech (ANSI and ICRA- weighted)[3], the ISTS[7], recorded passages in Kannada and English languages. The rainbow passage in English (Fairbanks, 1960) and a standard Kannada passage[13] were recorded by a female native speaker of Kannada who was fluent in English as well. The recording was done using Adobe Audition version 3.0 in a quiet environment with a condenser microphone placed at around 6 inches away from the mouth of the speaker at 00 azimuth. All the stimuli were edited to remove unwanted sounds like lip smacking and breathing sounds during speech. All the stimuli were normalized and were calibrated to have an equal RMS. The LTASS of the stimuli used in the present study were obtained using one third octave bands using ANSI standards as given in Figure 1.

A total of 30 individuals in the age range of 18- 26 years (mean age = 21.61; SD = 2.55) were included in the current study. As cerumen or other debris affects the placement for real ear measurement[15],

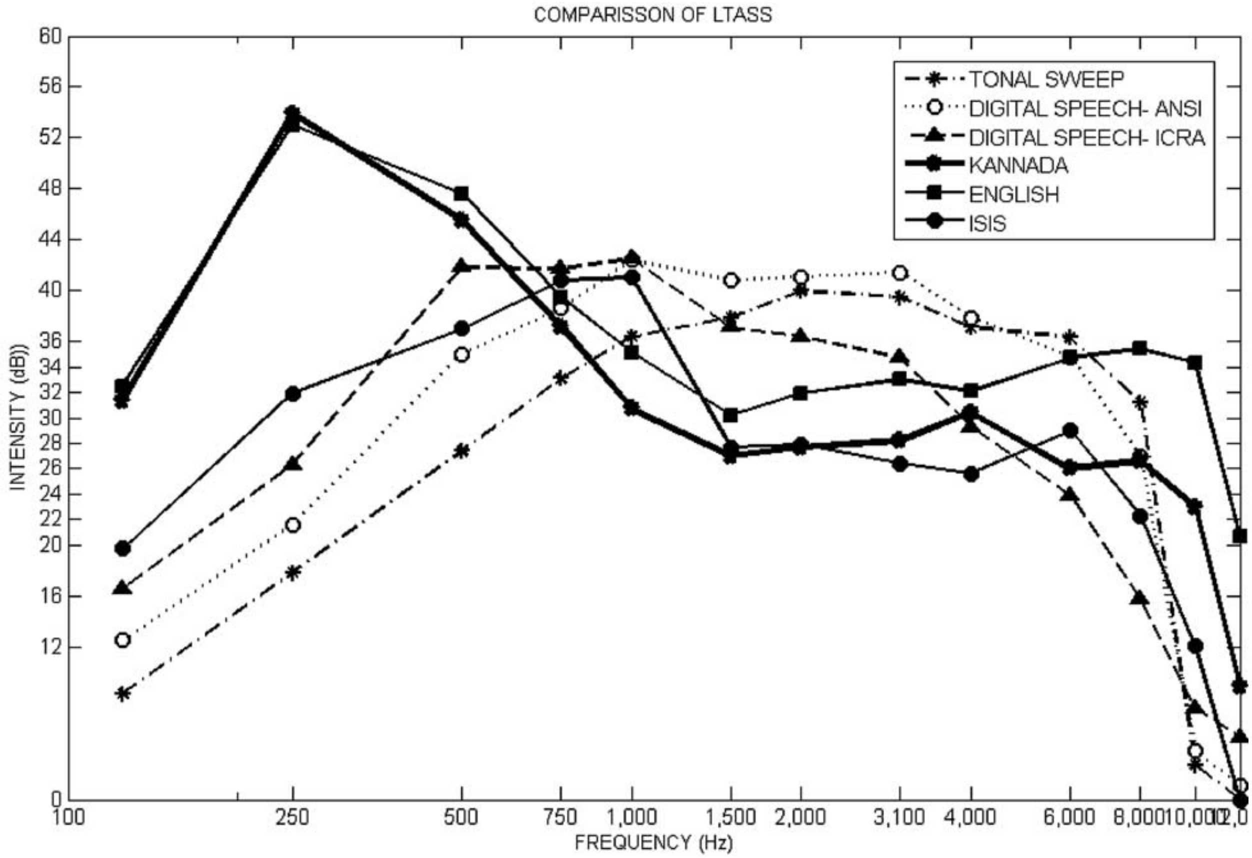

Fig. 1 Comparison of LTASS of the stimuli used in the study.

otoscopic examination was carried out on each individual ear. Individuals having clear ear canal, with no presence or history of infection and having 'A' type of tympanogram in immitance evaluation were selected for the study. The participant was made to sit 12 inches away from the speaker of the Fonix® 7000 real ear measurement (REM) system. Probe microphone was inserted into the participant's ear canal. The acoustic positioning procedure given by ANSI S3. 46[16] and ISO 12124[17] standards was used, by presenting 65 dB SPL of composite noise through the REM system, to place probe microphone in the ear canal. Once the positioning of the probe tube was done, the source of the REM was switched off. Then, the participant was seated at one meter distance from the speakers of caliberatedMA53 audiometer through which the actual test stimuli were presented.

A HP laptop was connected to the MA53 dual channel diagnostic audiometer for routing the stimuli. The audiometer was connected to two loudspeakers placed at 45 degrees azimuth The probe microphone of REM was used to record the sound pressure level as shown in Figure 2. The entire procedure was carried out in a sound treated, air conditioned, double room set-up. It was ensured that the noise level of the test setup was within the permissible limits[18].

The target stimuli from the laptop were routed through the calibrated audiometer. The presentation level of the stimuli was maintained at a constant level. The stimuli were presented from the corresponding speaker placed at 45 degrees azimuth at a distance of 1 meter. The speaker and the reference microphone of Fonix® 7000 were disabled. The measurement of stimuli at the ear canal and the presentations of stimuli were done simultaneously for each stimulus. The recording was done using the Fonix® 7000 equipment. The real ear SPL at the ear canal was obtained from 250 Hz to 8000 Hz at the octave and the

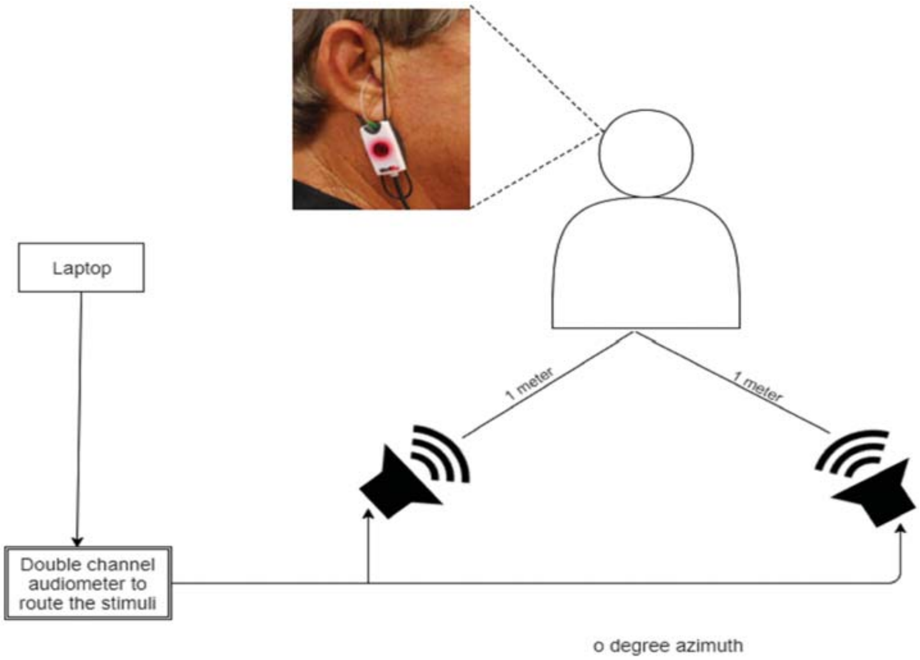

Fig. 2 The experimental setup used.

mid-octave frequencies for each stimulus. Using the same set up and the procedure, the experiment was repeated after a week on all the participants to check the reliability of the measurement.

3. RESULTS

The statistical analysis of the measured SPL was carried out using Statistical Package for Social Sciences (SPSS, version 17.0). The normality test for the data was carried out using One Sample Kolmogorov-Smirnov test and the results exhibited a normal distribution. Hence, parametric tests were carried out. The mean and standard deviation of the SPL across stimuli are shown in Figure 3. The SPL obtained were analyzed across the frequency, across stimuli and the interaction effect between the stimulus and the frequency.

3.1 Analysis of sound pressure level across stimuli

The SPL obtained across different stimuli irrespective of the frequencies were analyzed. The results of this are given in the Figure 4. The mean SPL obtained for Kannada and English were comparatively higher than those obtained for other non-speech and tonal stimuli as shown in the Figure 4. The SPLs were analyzed using two-way repeated measures ANOVA. The results showed a significant difference across stimuli ($F= 28.0$, $df = 5$, $p < 0.001$). Further, the Bonferroni pair-wise comparison was carried out. Among the stimuli used, SPL of ISTS stimulus was significantly different from all the other stimuli. Tonal stimulus was also significantly different from Kannada passage, English passage and Digital speech (ANSI and ICRA- weighted). However, there was no significant difference between the SPL of tonal sweep and ISTS stimulus. The results also revealed a lack of significant difference between the digital speech stimuli (ANSI and ICRA- weighted) and the recorded speech stimuli (Kannada & Indian English) as shown in Table 1.

3.2 Analysis of sound pressure level across frequencies

The SPL obtained across different frequencies were analyzed using two- way repeated measures ANOVA. There was a significant difference observed ($F= 126.29$, $df= 9$, $p< 0.001$). Bonferoni pair-wise

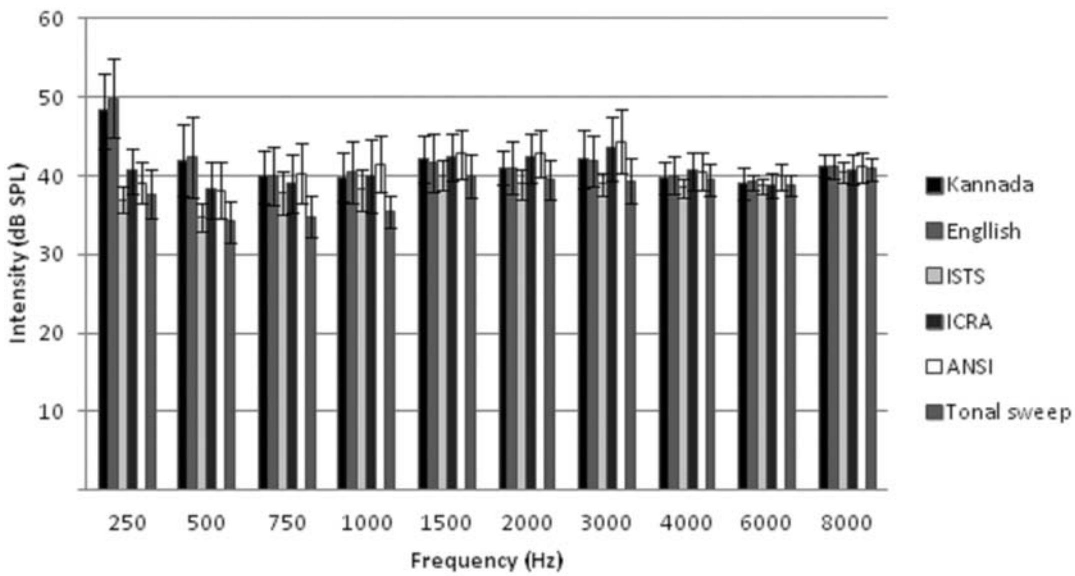

Fig. 3 Mean and SD of the stimuli across octaves and mid octaves.

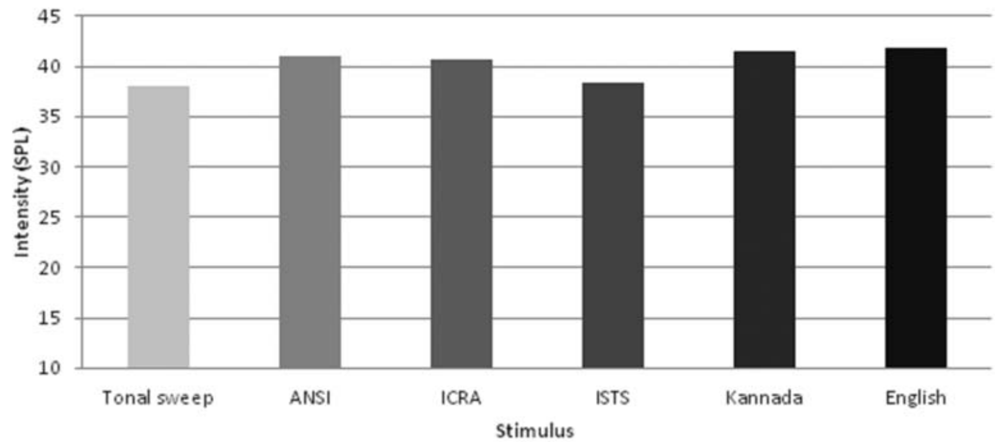

Fig. 4 Overall SPL differences across the stimuli.

Table 1. Results of Bonferoni pair-wise comparison of SPL across stimulus.

Stimulus (I)	Stimuli (J)	Mean difference (I-J)
Tonal sweep	Digital speech- ANSI	-3.049**
	Digital speech- ICRA	-2.628**
	Kannada passage	-3.537**
	English passage	-3.750**
Digital speech- ANSI	Tonal sweep	3.049**
	ISTS	2.702**
Digital speech- ICRA	Tonal sweep	2.628**
	ISTS	2.281**
ISTS	Kannada passage	-3.190**
	English passage	-3.403**

Note: ** $p < 0.01$

Table 2. Results of Bonferoni pair-wise comparison of SPL across frequencies.

Frequency (I) (Hz)	Frequency (J) (Hz)	Mean difference (I-J)
250	500	2.801**
	750	2.652**
	1000	2.680**
	1500	3.610**
	2000	1.946**
	6000	-1.174**
	8000	-3.161**
500	3000	-3.413**
	4000	-2.224**
	6000	-3.974**
	8000	-5.961**
750	1500	0.958*
	3000	-3.264**
	4000	-2.075**
	6000	-3.826**
	8000	-5.812**
1000	1500	0.930**
	3000	-3.292**
	4000	-2.103**
	6000	-3.854**
	8000	-5.841**
1500	2000	-1.664**
	3000	-4.222**
	4000	-3.033**
	6000	-4.784**
	8000	-6.771**
2000	3000	-2.558**
	4000	-1.369**
	6000	-3.120**
	8000	-5.107**
3000	4000	1.189*
	8000	-2.548**
4000	6000	-1.751**
	8000	-3.737**
6000	8000	-1.987**

Note: *$p < 0.05$,** $p < 0.01$

comparison of frequencies was carried out. As given in Table 2, the SPL obtained at 8 kHz was significantly different from that obtained at other frequencies (250 Hz to 6 kHz). The SPL at 500 Hz, 750 Hz, 1 kHz and 2 kHz was significantly different from the SPL at all other frequencies, however, the SPL obtained at these frequencies were not significantly different among themselves. Further, the SPL at 250 Hz was significantly different from the SPL obtained at all other frequencies except 3 kHz and 4 kHz, and the SPL at 1500 Hz was significantly different from the SPL at all frequencies except at 500 Hz. Similarly, there was no significant difference between SPL obtained between 6 kHz and 3 kHz. This suggests that the SPL at low frequency region is significantly higher than in the other frequency regions of the stimuli.

3.3 Analysis of stimulus- frequency interaction

The stimulus-frequency interactions of the SPL were analyzed using two way repeated measures ANOVA. The results showed a significant difference (F= 20.45, df= 45, p< 0.001). To analyze the interaction of stimulus with each frequency separately, one-way repeated measures ANOVA was carried out. There was a significant difference in SPL obtained at all the frequencies except at 6000 Hz and 8000Hz as given in the Table 3. Hence, to find the stimulus pair having significant difference at each frequency, a pair-wise comparison using Bonferoni test was carried out.

Table 3. Results of One- Way Repeated Measures ANOVA for stimulus - frequency interaction.

Parameter	df	F
Stimulus*250 Hz	5	72.290**
Stimulus*500 Hz	5	27.013**
Stimulus*750 Hz	5	13.683**
Stimulus*1000 Hz	5	13.744**
Stimulus*1500 Hz	5	5.518**
Stimulus*2000 Hz	5	10.529**
Stimulus*3000 Hz	5	13.499**
Stimulus*4000 Hz	5	4.341**

Note: ** p < 0.01

The results of Bonferoni pair-wise comparison of stimulus-frequency interaction are given in Table 4. The SPL of the ISTS was significantly different from other stimuli in most of the frequencies in the range of 250 Hz to 3000 Hz. There was no significant difference in SPL observed between Kannada, Indian English and digital speech (ANSI and ICRA- weighted) from 750 Hz to 4000 Hz. The SPL of tonal sweep stimulus was significantly different from all the other stimuli in majority of frequencies.

Table 4. Bonferoni pair-wise comparison of stimulus- frequency interaction.

Frequency	Stimulus (I)	Stimulus (J)	I-J
250 Hz	Tonal sweep	Digital speech- ICRA	-2.973*
		Kannada passage	-10.570**
		English passage	-12.207**
	Digital speech- ANSI	ISTS	2.113*
		Kannada passage	-9.173**
		English passage	-10.810**
	Digital speech- ICRA	ISTS	3.690**
		Kannada passage	-7.597**
		English passage	-9.233**
	ISTS	Kannada passage	-11.287**
		English passage	-12.923**
500 Hz	Tonal sweep	Digital speech- ANSI	-3.980**
		Digital speech- ICRA	-4.113**
		Kannada passage	-7.837**
		English passage	-8.167**
	Digital speech- ANSI	ISTS	3.410**
		Kannada passage	-3.857*
		English passage	-4.187*

Conted.....

	Digital speech- ICRA	ISTS	3.543**
		Kannada passage	-3.723*
		English passage	-4.053*
	ISTS	Kannada passage	-7.267**
		English passage	-7.597**
750Hz	Tonal sweep	Digital speech- ANSI	-5.477**
		Digital speech- ICRA	-4.290**
		ISTS	-3.097**
		Kannada passage	-5.157**
		English passage	-5.180**
1000Hz	Tonal sweep	Digital speech- ANSI	-6.087**
		Digital speech- ICRA	-4.497**
		ISTS	-2.783**
		Kannada passage	-4.420**
		English passage	-5.003**
	Digital speech- ANSI	ISTS	3.303**
	ISTS	English passage	-2.220*
1500Hz	Tonal sweep	Digital speech- ANSI	-2.823*
		Digital speech- ICRA	-2.340*
	Digital speech- ANSI	ISTS	2.690**
	Digital speech- ICRA	ISTS	2.207*
2000Hz	Tonal sweep	Digital speech- ANSI	-3.337**
		Digital speech- ICRA	-2.740*
	Digital speech- ANSI	ISTS	3.960**
	Digital speech- ICRA	ISTS	3.363**
3000Hz	Tonal sweep	Digital speech- ANSI	-4.980**
		Digital speech- ICRA	-4.223**
		English passage	-2.543*
	Digital speech- ANSI	ISTS	5.347**
	Digital speech- ICRA	ISTS	4.590**
	ISTS	Kannada passage	-3.170*
		English passage	-2.910**
4000Hz	Digital speech- ANSI	ISTS	2.007*
	Digital speech- ICRA	ISTS	2.100**
	ISTS	English passage	-1.587*

Note: $p < 0.05$, ** $p < 0.01$

3.4 Reliability of the measured SPL

The SPL obtained across different stimuli were analyzed for reliability using Cronbach's Alpha model. The SPL obtained in the frequency range of 250 Hz to 8000 Hz were combined separately for each stimulus. The SPLs obtained between two trials were compared and a difference of 3-4 dB was observed between both the trials. The results of this are shown in Table 5. The results reveal a good reliability between the SPL measured in both the trials.

Table 5. Reliability assessment of SPL measurements.

Stimulus	Cronbach's Alpha
Tonal sweep	0.656
Digital speech- ANSI	0.832
Digital speech- ICRA	0.783
ISTS	0.661
Kannada passage	0.716
English passage	0.793

4. DISCUSSION

The aim of the current study was to compare the SPL measured at the ear canal for a passage in Kannada and Indian English with the standard stimuli available in the real ear measurement systems like the tonal sweep stimuli, digital speech (ANSI and ICRA- weighted) stimuli and the ISTS.

4.1 Analysis of SPL across stimuli

The analysis of SPL across stimuli revealed that, the tonal sweep and ISTS stimuli were significantly different from all the other speech and non speech stimuli. Further, the difference between the tonal sweep stimuli and ISTS were insignificant. This could be attributed to the absence of suprasegmentals and segmentals in both the stimuli.

There was no statistical difference between the SPL obtained for the passages in Kannada and Indian English. The probable reason for this could be explained by the fact that both languages were spoken by the same individual thereby reducing the differences in vocal tract dimension, energy distribution across time and the vocal effort [19]. Wiltshire and Harnsberger [20] also reported an influence of native language on both the segmental as well as the suprasegmental aspects of speech. There was also no significant difference observed between the SPL obtained for the digital speech (ANSI and ICRA- weighted) stimuli and the recorded passages (Kannada and Indian English).

Further, there was significant difference between ISTS and the passages. The ISTS stimulus has been constructed with segmentals obtained from six different International languages other than Indian languages. English is one of the languages used in ISTS[7]. In this study, English passage was also spoken by a female speaker from karnataka. Hence, due to the influence of the native language there could be changes in the segmentals and suprasegmentals during production, which in turn would have caused a larger SPL at low and mid frequencies[14]. Further, in connected speech, due to increased vocal effort, the SPL decreases towards the end of the sentence. As ISTS stimulus lack these subtle variations of connected speech, the SPL obtained might have been lowered.

4.2 Analysis of SPL across frequencies

The analysis of SPL across frequencies revealed that the energy of the stimuli at lower frequencies was significantly higher than those obtained at the higher frequencies. Similar finding has also been reported in few other studies[8] [21] [22]. The reason for this could be due to the properties of the signal.

The low frequency sounds have longer wavelengths than the high frequency sounds and hence, low frequencies are least absorbed by the head and torso[21]. Further, it could also be that, as the SPL was recorded at the level of the ear canal, the resonance of the ear canal which is around 2.5 kHz[23] could have also contributed to the results by enhancing mid frequencies than high frequencies.

4.3 Analysis of stimulus- frequency interaction

At most of the frequencies (except 6 kHz and 8 kHz), the SPL obtained for the ISTS stimulus was different from that of the recorded passages of Kannada and Indian English. This difference could be attributed to the differences in terms of segmentals and suprasegmentals between the ISTS and the recorded passages as explained previously. The suprasegmentals have more energy at lower frequencies. As there is a lack of these suprasegmentals in ISTS, there could have been a greater difference in energy in the low frequency region. The difference in the mid and high frequency region could be due to the segmental variations seen from that of the ISTS stimulus, as the ISTS stimuli do not include any of the Indian languages.

Further, the SPL across the recorded passages in Kannada and Indian English were similar. As explained earlier, this could be due to the fact that, the segmental and suprasegmentals in the Indian English [24] are similar when spoken by a native female speaker of an Indian language.

At mid frequencies from 750 Hz to 4 kHz, the differences between the passages and the digital speech stimuli were negligible. This reflects the similarities in the frequency composition. Hence, it is clear that ANSI weighted and ICRA weighted digital speech closely resembles the spectra of Kannada and Indian English. This is also clear from the LTASS of the stimuli as shown in Figure 1.

Another observation made was that the mean F0 (fundamental frequency) of the individual in the recorded passages was around 210 Hz and the mean F0 used in the ISTS was around 190 Hz. Hence, the speaker differences would not have caused greater changes in SPL across frequencies.

4.4 Reliability of the measured SPL

The reliability of the results was verified by repeating the procedure in the same settings, a week later. The result showed a good reliability. Hence, the obtained results are reliable. In literature, studies have reported a mean difference of about 3- 6 dB in test- retest results of insertion gain measurements. Further, the real ear measurements have been reported to have good short term reliability [25] [26]. The results of the present study also support this view.

5. CONCLUSION

The characteristics of ISTS differed from the Kannada language and Indian English. The ISTS lacks the suprasegmentals that are presented in connecting speech and this would have contributed to the differences obtained in SPL at low frequencies. Hence, it is important to keep in mind that fitting and verification of hearing aids using the ISTS would probably differ for native Kannada speakers. The use of the ISTS for verification of hearing aids in the context of Kannada and Indian English should be done with caution as there are clear differences between ISTS, Kannada and Indian English. Hence, when hearing aids are fitted with verification by using ISTS stimulus, there are chances for the required gain to be underestimated. The results could be more generalizable, if carried out with multiple talkers as this would reduce the effect of talker variability.

6. AKNOWLEDGEMENT

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Molecular interaction of diclofenac and aceclofenac NSAIDs in methanol-water mixture : An ultrasonic investigation

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ABSTRACT

Different acoustic parameters such as adiabatic compressibility (β_s) , specific acoustic impedance (Z), Intermolecular free length (L_f), relative Association (R_a), apparent molar volume ($V_Ø$), partial molar volume ($V_Ø{}^0$), apparent molar compressibility(KØ), partial molar compressibility($K_Ø{}^0$), solvation number (S_n), of two non steroid anti inflammatory drug aceclofenac and diclofenac in 10%, 30%, 50% methanol has been determined from ultrasonic velocity(U), density(d) of the solution at 303.15k, 308.15k, 313.15k. For aceclofenac especially at 50% methanol all the characteristic property changes drastically due to structural deformation which is verified from shift of λ_{max} in UV-VIS spectra at the said percentage of methanol. The structural changes are not so prominent in case of diclofenac although there is a change in trend at 50% methanol. The parameter S_k and S_v was calculated using Mason's equation to interpret ion-ion, ion-solvent interaction. The results were interpreted in the light of structure-making or structure-breaking effects of diclofenac and aceclofenac in the aqua-organic (protic) solvent justifying their biological activities. As per the variation of acoustic parameters of two drugs it was visualised that there is less ion-solvent interaction in aceclofenac a better drug.

1. INTRODUCTION

Drug-water interaction and their temperature dependence play a significant role in understanding the drug action at molecular level. Such results are useful for predicting the absorption of drug, transport of drug across biological membrane[1,2]. The mechanism of this molecular process is not clearly understood because it is difficult to carry out direct study of drugs in physiological system. Thermodynamic properties are appropriate parameters for interpreting solute-solvent, solute-solute interaction in solution phase. Ultrasonic velocity measurement of the drug in solution and calculation of various parameters provide useful information regarding nature of molecular interaction of the drug and physicochemical properties of the solution[3, 4, 5, 6, 7].

Non steroid anti-inflammatory drugs (NSAID) are the backbone of acute pain therapy, among which diclofenac sodium is one of the potent and time tested, commonly prescribed drug. Diclofenac is a non-selective inhibitor of cyclooxygenase and also appears to reduce synthesis of leukotrienes. Being a non-selective inhibitor, it is associated with gastrointestinal adverse effects, thereby limiting its use in patients predisposed to gastrointestinal motility. Aceclofenac has anti-inflammatory properties similar to those of diclofenac and yields good results in the control of dental pain. Aceclofenac, being a predominantly cox-2 inhibitor, demonstrates improved gastrointestinal tolerability compared to conventional NSAIDs. They do not have any significant effect on platelet functions as non-selective inhibitors. Non-steroidal anti-inflammatory drugs (NSAIDs) are amphiphilic molecules having hydrophobic and hydrophilic domain. They are sparingly soluble in water due to hydrophobic nature and exhibit analgesic, antipyretic, anti-inflammatory and platelet inhibitory property[8, 9]. NSAIDs are useful as inhibitors for clotting in the blood vessels and thus help in the prevention of heart attack and strokes and in the prevention of colon cancer. The volumetric and viscometric properties of NSAIDs molecules have significant implications for permeation of the drug molecules through biological membranes. The interest in the nature of interactions of drugs with protic solvents is driven by both fundamental and practical considerations. Methanol and ethanol are normally present in drug delivery formulation. They act as carriers for delivery of drugs to different disease targets in a manner that provides maximum therapeutic activity. Thus, the behaviour of NSAID's in such solvents is of significance from pharmacological point of view. In the literature, most of the clinical studies have been done to evaluate the efficacy and safety of orally administered analgesics like diclofenac and aceclofenac[10].

Thakur *et al.* have studied the different acoustical parameters of binary mixture of 1-propanol and water. Volumetric, ultrasonic speed and viscometric studies of salbutamol sulphate in aqueous methanol solution at different temperatures has been investigated by K. Rajgopal *et al*. Ultrasonic and viscometric behaviour of azithromycin with different solvent systems dioxane-water and methanol-water mixture at 305.15 K has been studied by S.A.Quazi1 *et al.*[11, 12]. Acoustical study of drug colimax in methanol was done by S.K. Thakur *et al.* Ultrasonic studies in solution of three hydrate drugs in methanol have been investigated by N.Jayamadhuri and her co-workers.

Acoustical parameters of hybrid drugs of ambroxol hydrochloride at 300.15K was investigated by Chapke Ujjwal *et al.* Literature survey indicates that no work has been done on ultrasonic study of diclofenac and aceclofenac in aqueous methanol medium. This prompts us to carry out this piece of research work.

Diclofenac and aceclofenac both are non steroid anti inflammatory drugs used for treatment of osteoarthritis, rheumatoid arthritis, migraines and also used for relief of pain. The present work deals with measurement of density (d), ultrasonic velocity (U), apparent molar volume ($V_ø$), apparent molar compressibility ($K_ø$), adiabatic compressibility (β), partial molar volume ($V_ø^0$), partial molar compressibility ($K_ø^0$), specific acoustic impedance (z), intermolecular free length (L_f), solvation number (S_n), relative association (R_a) of these drugs in aqua-organic (protic) solvent media. These parameters are discussed in terms of solute-solvent, solute-solute interaction. This will be helpful to predict the mechanism of drug action in biological domain[13, 14].

2. EXPERIMENTAL DETAILS

Sodium diclofenac and aceclofenac of AR Grade were procured from Sigma Aldrich company methanol from Merck. Tripled distilled water was used throughout the experiment. Ultrasonic velocity was measured using single crystal ultrasonic interferometer (Model-81-C) operating at a frequency of 2 M Hz with an accuracy of ± 0.1 ms-1. The density of pure component and binary mixture was measured using pre-calibrated pyknometer. The temperature was maintained by thermostatic regulated water bath connected to ultrasonic interferometer. Density and speed of sound measurement of the samples prepared (using Sartorius CPA 225D balance having precision of ±0.00001 g). UV spectra were recorded by Carry 100 Agilent technology UV-VISIBLE spectrophotometer.

3. RESULTS AND DISCUSSIONS

3.1 Interaction of drug with methanol

The molecular structure of Aceclofenac and Diclofenac are shown in figure 1(a), (b).

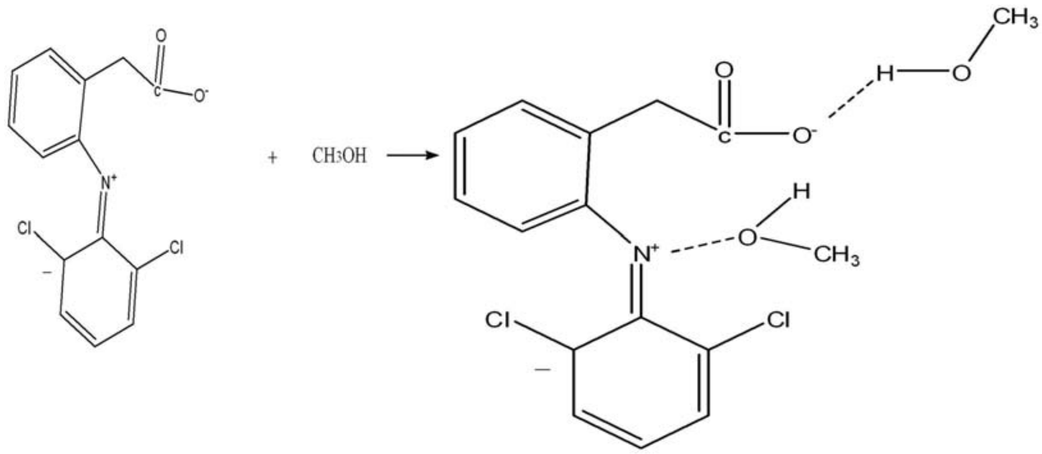

Fig. 1 (a). Interaction of DFS with Methanol

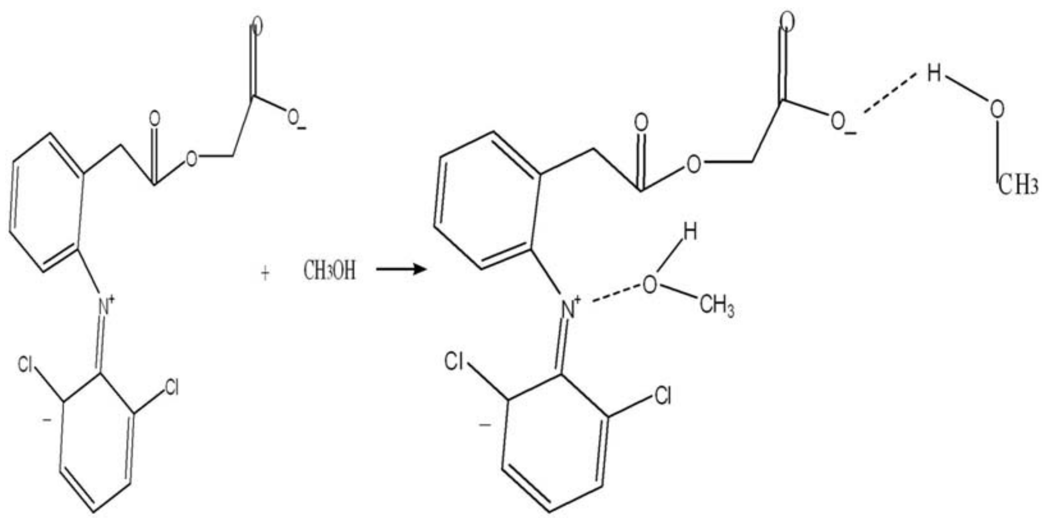

Fig. 1 (b). Interaction of ACE with Methanol

Both Aceclofenac and Diclofenac form different H- bonding due to difference in their bulk structure and conjugation; their behaviour towards solvent is different. It is verified from UV-VIS spectra of both the drugs at variable % of Methanol [Figure 2(a), (b)].

Ultrasonic investigation of these two drugs have been carried out in methanol-water medium (10%, 30%, 50%) varying the concentration from (0.000, 0.002, 0.004, and 0.006, 0.008, 0.01) mol·kg^{-1} measured at T = (303.15, 308.15 and 313.15) K the density and ultrasonic velocity are reported in table-1. Various interacting parameters such as adiabatic compressibility (β_s), specific acoustic impedance (Z), adiabatic compressibility (β_s) intermolecular free length (L_f), relative association (R_A) are reported in table-1. Apparent molar volume ($V_ø$), partial molar volume ($V_ø^0$), apparent molar compressibility ($K_ø$), partial molar compressibility ($K_ø^0$), solvation number (S_n), S_k, S_v parameters derived from Masson's equation.

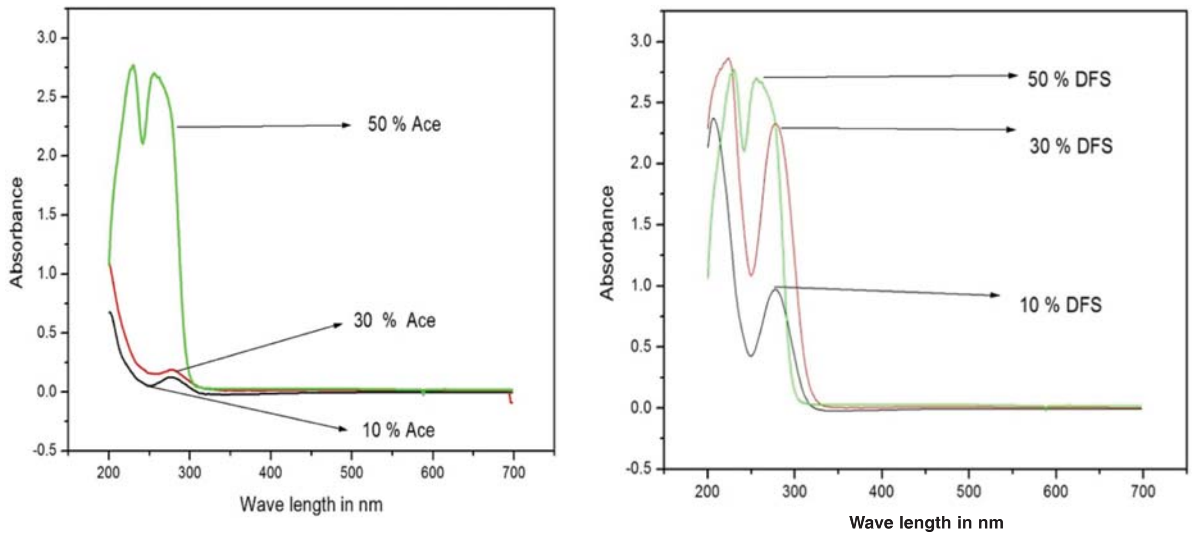

Fig. 2 UV-VIS Spectra of (a) Aceclofenac and (b) Diclofenac with different % of Methanol

Experimental evidence indicates that density is a linear function of molar concentration of drugs. The increase in density was due to shrinkage in volume which is due to presence of drug molecule in solution. So the increase in density may be attributed to structure breaker ability of methanol-water mixture in presence of drug.

3.2 Variation of apparent molar volume (V_ϕ) of NSAID with % of methanol :

The apparent molar volume was calculated by using equation (1)

$$V_\varnothing = \frac{M}{d_0} - \left[\frac{d-d_0}{d_0}\right]\frac{1000}{m} \quad (1)$$

m - Molality in (mol kg^{-1})

M - Molecular mass of the solute (mol kg^{-1})

d_0, d are density of solvent and solute (Kg m^{-3}).

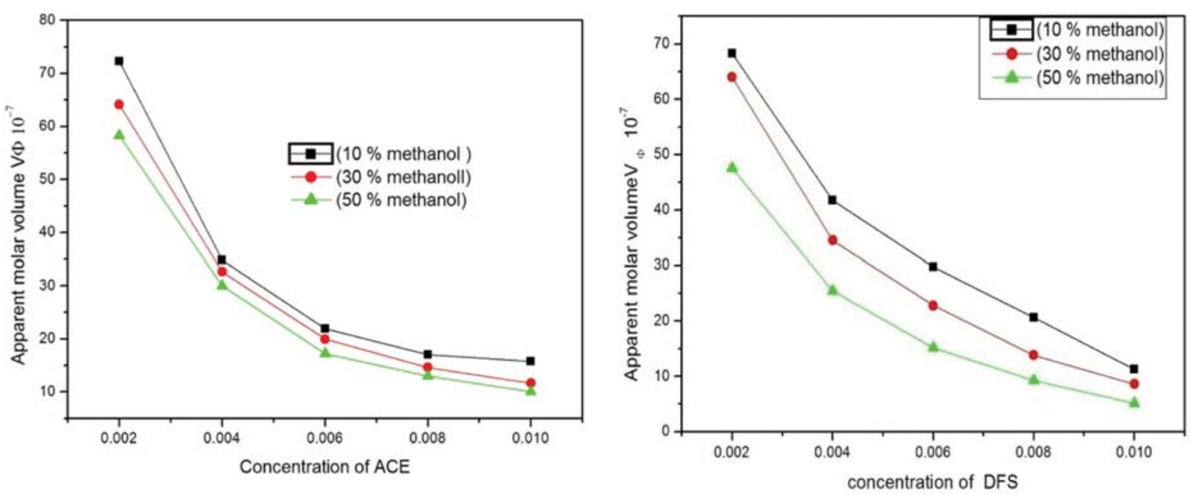

Fig. 3 Variation of apparent molar volume of (a) ACE and (b) DFS with concentration in different % of methanol

The plot of apparent molar volume against concentration of both the drugs are graphically presented in fig 3(a) and 3(b). These values decrease for both the drugs with increase in concentration of methanol from 10% to 50% the apparent molar volume decreases which indicates less interaction of drug in methanol. However with increase in methanol content the relative permittivity of the medium decrease at given temperature, hence lower permittivity promotes greater binding of drug with solvent.

3.3 Variation of adiabatic compressibility (β) of NSAID with % of methanol :

Adiabatic compressibility is calculated by using the equation :

$$\beta = \frac{1}{u^2 d} \tag{2}$$

Where U - Ultrasonic velocity

d - Density of solution

From ultrasonic velocity at three different temperatures adiabatic compressibility are calculated and the results are graphically represented by figure 4 (a), (b) .It is a measure of intermolecular association or dissociation or repulsion. Here the β value increases due to structural changes occurring in the solution and association taking place between the drug and solvent. The increase in β value is due to assemble of solvent molecules around the ions supporting weak ion solvent interaction. [15] The decrease in β value is observed as molar concentration increases from 0.002 to 0.006 mol Kg^{-1} for both aceclophenac and diclophenac in 10% and 30% methanol media but at higher concentration of drug increase in β value justifies weak ion solvent interaction. At 50% of methanol the behaviour of both aceclofenac and diclofenac are different. The different behaviour is partly due to solvation stabilization of protic co-solvent (methanol) through H-bonding. The decrease in β value indicates drug-methanol interaction, but at lower concentration the β increases due to release of solvent molecule from inner sphere to the bulk solution. The enhancement of adiabatic compressibility in ACE up to drug concentration 0.006 M is noticed. Then it decreased sharply due to strong drug-methanol hydrogen bonding. But there was continuous fall in DFS system at all concentrations of drug showing weak ion- dipole interaction. In ACE system with rise in temperature the value increased due to structure breaking nature of the drug at high temperature, where as the reverse trend in DFS at high temperature is due to strong ion-dipole interaction.

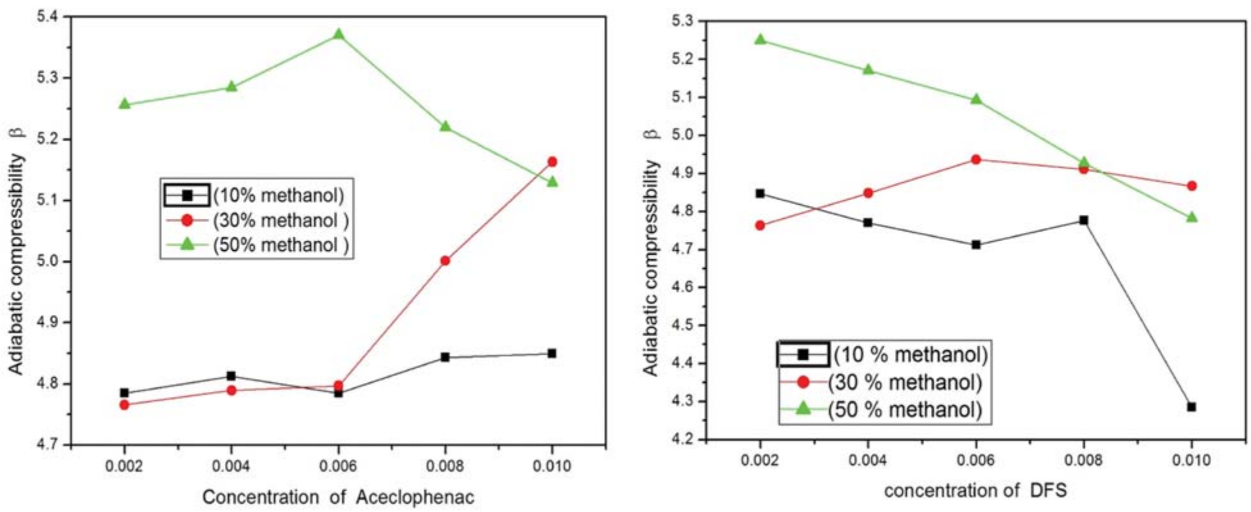

Fig. 4 Variation of adiabatic compressibility of (a) ACE and (b) DFS with concentration in different % of methanol.

Conted......

3.4 Variation of apparent molar compressibility (K_Φ) of NSAID with % of methanol

The apparent molar compressibility is calculated by using the relation

$$K_\Phi = \frac{1000}{md_0}[\beta - \beta_0] + \beta\ \phi_v \tag{3}$$

Variation of apparent molar adiabatic compressibility of ACE and DFS with concentration in different % of methanol is graphically represented in fig 5(a) and 5(b). It almost remains constant for 10% and 30% methanol solution but at 50% methanol the values are higher for both the drugs and it increases as the concentration increase. The K_ϕ is normally positive and small for hydrophobic compounds and it provides information regarding hydrophobic and electrostatic attraction[16,17]. In the present study, the positive values of K_ϕ^0 indicate that water molecules around these drugs would exercise less resistance to compress the bulk solution.

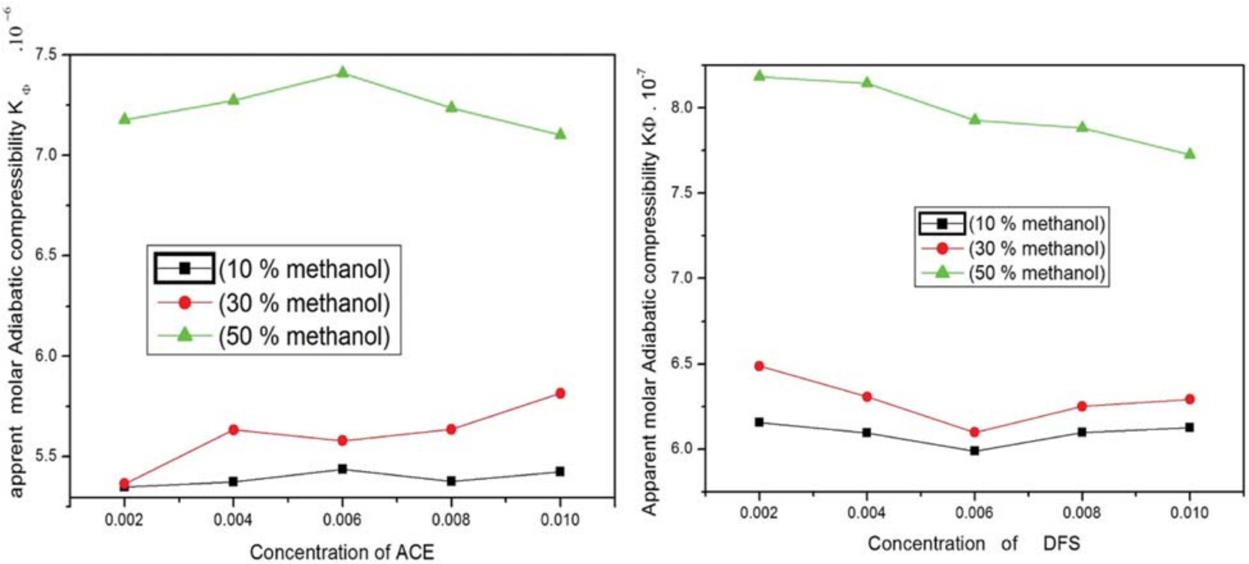

Fig. 5 Variation of apparent molar adiabatic compressibility of
(a) ACE and (b) DFS with concentration in different % of methanol

3.5 Variation of intermolecular Free Length (L_f) of NSAID with % of methanol

Intermolecular free length has been evaluated by formula

$$L_F = K\sqrt{\beta s} \tag{4}$$

K - Jacobson constant,

β_s -Compressibility parameter of the solution

Intermolecular free length is a measure of intermolecular force which depends upon the distance of centre of molecule. It is graphically represented in fig 6(a), 6(b). For diclofenac system at 30% methanol solution the L_f value increase with concentration up-to 0.006 mol kg^{-1} and then at higher concentration it falls. The value decrease up-to 0.006 mol kg^{-1} and then increases for 10%, methanol. But at 50% methanol the value decrease constantly due to solvent-solvent interaction. In Aceclofenac at 10%, 30%, methanol solution the L_f value goes on increasing indicating structure breaking behaviour of the drug[18-21]. But for 50% the increase in intermolecular free length with concentration is due to enhanced molecular association between drug molecule and solvent up to 0.006 mol kg^{-1} and then there is a sharp decrease probably due to strong hydrogen bonding between methanol and water. As the repulsive force depends

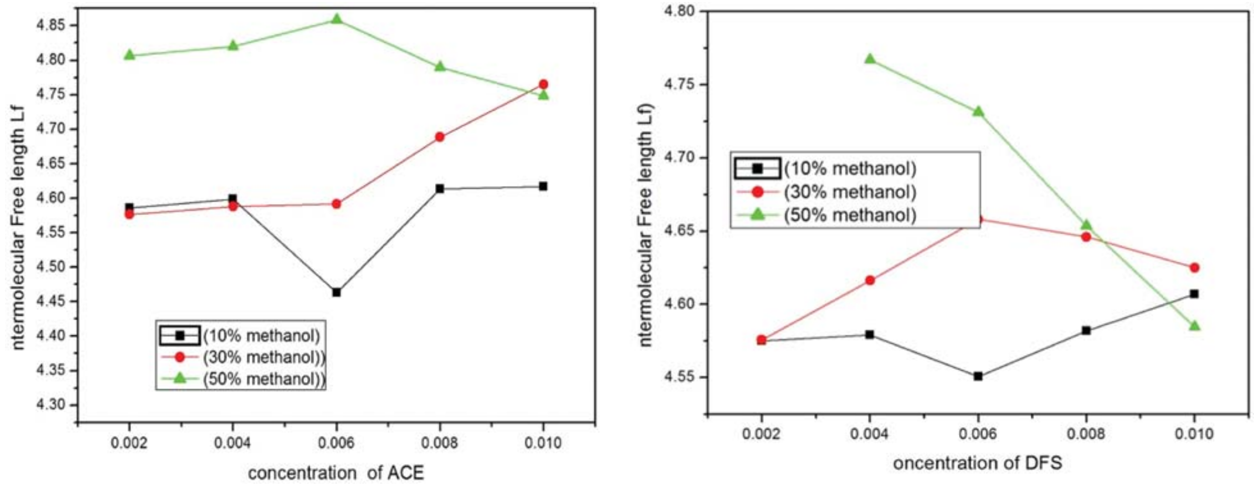

Fig. 6 Variation of intermolecular free length of (a) ACE and (b) DFS with concentration in different % of methanol

upon the distance between surface of the molecules, evidently in this case the disturbance between centre of the molecules and surface of the molecules are reflected as intermolecular free length. It is observed that the value of intermolecular free length increase in both the system with increase in temperature supporting thermal expansion of the component molecule of the drug solution.

3.6 Variation of Acoustic Impedance (Z) of NSAID with % of methanol

Intermolecular free length has been evaluated by formula

$$Z = d.U \tag{5}$$

d - Density of solution

U - ultrasonic velocity

Acoustic impedance is governed by inertial and elastic properties of the medium. The Z value suggests how much resistance the medium provide to the propagated ultrasonic sound. The result shows the resistance for both the drugs are executed in different force of the medium depending upon the solute -

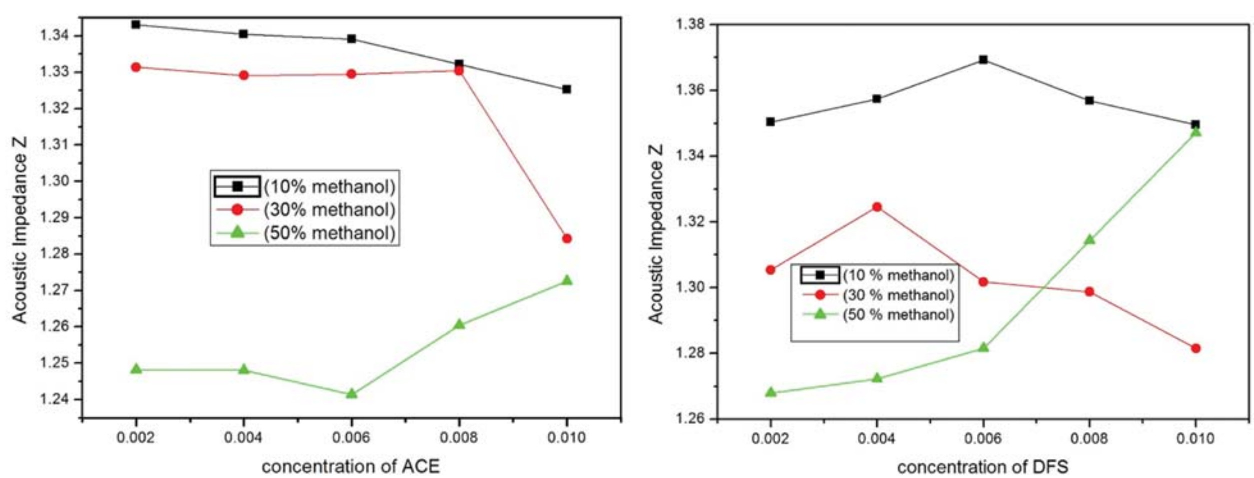

Fig. 7 Variation of acoustic impedance of (a) ACE and (b) DFS with concentration in different % of methanol

solvent and solvent-solvent interaction. The value of Z is graphically recorded in fig 7(a), 7(b). For Aceclofenac at 10% & 30% methanol acoustic impedance decrease up to 0.006 mol kg^{-1} slowly and then there is a sharp decrease indicating structure formation. But in 50% methanol the acoustic impedance value decreases up to 0.006 mol kg^{-1} and then increases due to structure breaking property. Whereas for Diclofenac at 50% methanol the Z value increases for all drug concentration and for 10% and 30% it first increases then decreases. It can be attributed to the concept that with increase in concentration of drug the thickness of ionic atmosphere increases due to decrease in ionic strength and as a result acoustic impedance decreases[22-23]. It is observed that at the range of 0.006 0.008 mol kg^{-1} concentration the acoustic behaviour of drug drastically changes in presence of a protic solvent. Here the escalation of acoustic impedance with increase in temperature for both the drugs shows less drug-solvent molecular interaction.

3.7 Variation of Relative Association (R_A) of NSAID with % of methanol

The relative association is a measure of solute-solute or solute-solvent interaction. Relative association is measured by the equation.

$$R_A = (d_0 / d)\left(\frac{U_0}{U}\right)1/2 \tag{6}$$

d_0 - density of solvent d-density of solution

U_0 - ultrasonic velocity of solvent,

U - ultrasonic velocity of solution

The experimental value of relative association are graphically represented by figure 8(a), (b). In 10%, 30% methanol solution the relative association value remain constant. The value is slightly greater for 30% methanol but in 50% methanol the R_A value substantially increases for both the drug Aceclofenac and Diclofenac, which suggest strong solute-solvent interaction[24]. The shifting of peak at 50% methanol with drug in UV-VIS spectra clearly justifies the strong solute-solvent association at high drug concentration.

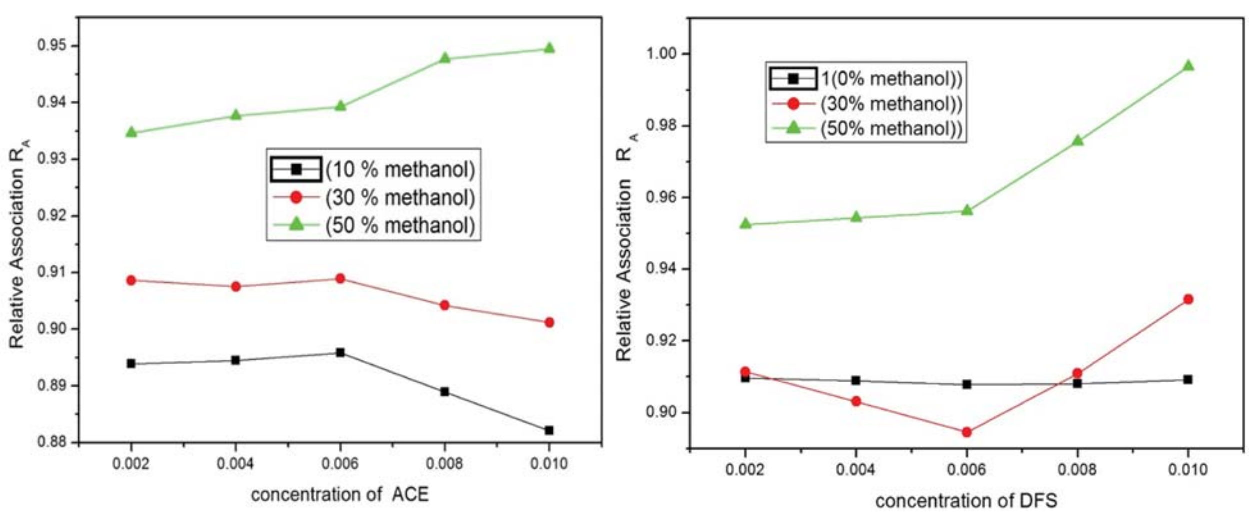

Fig. 8 Variation of Relative Association (a) ACE and (b) DFS with concentration in different % of methanol.

3.8 Variation of Solvation Number (S_n) of NSAID with % of methanol

Solvation number is a measure of structure making and structure breaking tendency of solute in solution. The parameter is calculated by the formula

$$S_n = \frac{M_2}{M_1}\left[1-\frac{\beta}{\beta_0}\right]\left[\frac{100-x}{x}\right] \quad (7)$$

M_1 - molecular wt of the solvent,

M_2 - molecular wt of solute

β - adiabatic compressibility of solution,

β_0 - adiabatic compressibility of solvent

The values of Sn are graphically represented by figure 9(a), (b). In 10%, 30% methanol the solvation number decrease suggesting structure breaking tendency of solute in solution for both Diclofenac and Aceclofenac[25]. In 50% methanol solution the solvation property suddenly changes. The remarkable shifting of peak here with drug in UV-VIS spectra indicates the new association of drug and solvent at hydrophilic end. Negative value of Sn here indicates the solution is more compressible than the solvent. Further its decrease in positive values support the structure intensifying property with increasing molecular concentration of drug-methanol system. The regular decrease in Solvation number with increase in temperature indicates the decrease in size of secondary layer of Solvation which implies strong solute-solvent interaction[26].

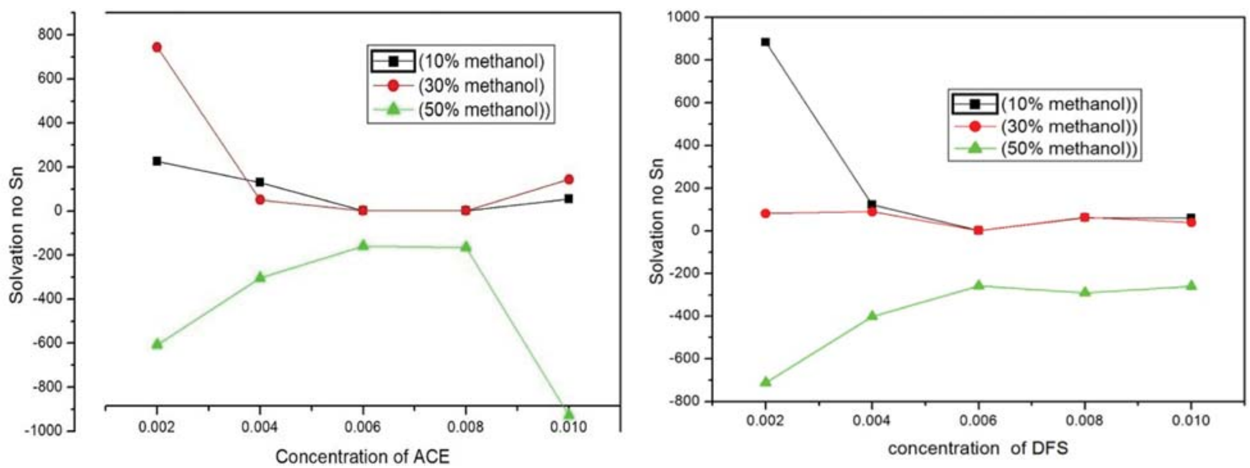

Fig. 9 Variation of Solvation Number (a) ACE and (b) DFS with concentration in different % of methanol.

The correlation analysis was carried out in Origin version 8.0 computer software. The goodness of fit is discussed using correlation coefficient and standard deviations. The R^2 value in all cases is found to be is greater than 0.99 and standard deviation is found to be 0.05%.

Table 1. The data of density *(d)*, ultrasonic velocity *(U)*, adiabatic compressibility *(β)*, acoustic impedance *(Z)*, intermolecular free length *(L_f)*, and relative association *(R_A)* of aqueous solution of diclofenac and aceclofenac in different mole fractions of methanol at *T* = (303.15, 308.15 and 313.15) K.

T / (K)	m / (mol kg^{-1})	ρ x 10^3 (kgm^{-3})	U / ($msec^1$)	β / m^2N^{-1}	Z / kg m^2sec^{-1}	L_f / m	R_A
Diclofenac in 10 % methanol							
303.15	0.002	873.8	1528.0	4.7461	1.3504	4.5749	0.9097
	0.004	874.3	1542.0	4.7706	1.3574	4.5791	0.9088
	0.006	876.6	1556.0	4.7117	1.3639	4.5507	0.9077

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	0.008	879.4	1543.0	4.7761	1.3569	4.5817	0.9081
	0.01	882.4	1543.0	4.9885	1.3495	4.6068	0.9091
308.15	0.002	872.4	1540.0	4.7785	1.3588	4.5829	0.9178
	0.004	873.8	1553.7	4.7121	1.3647	4.5509	0.9185
	0.006	875.2	1568.0	4.6472	1.3723	4.5195	0.9175
	0.008	877.8	1551.0	4.7356	1.3614	4.5623	0.9169
	0.01	880.9	1536.0	4.8116	1.3530	4.5987	0.9172
313.15	0.002	870.8	1524.0	4.8882	1.3423	4.6352	0.9243
	0.004	876.5	1554.3	4.7225	1.3621	4.5559	0.9255
	0.006	873.6	1584.2	4.5622	1.3837	4.4779	0.9282
	0.008	876.5	1564.0	4.6641	1.3614	4.6641	0.9273
	0.01	879.3	1544.0	4.7705	1.3576	4.6790	0.9263
Diclofenac in 30 % methanol							
303.15	0.002	829.5	1572.0	4.7635	1.3054	4.5757	0.9114
	0.004	833.2	1564.0	4.8483	1.3246	4.6162	0.9031
	0.006	836.6	1556.0	4.9369	1.3317	4.6582	0.8945
	0.008	854.0	1544.0	4.9113	1.2987	4.6661	0.9109
	0.01	875.7	1532.0	5.1666	1.2815	4.6949	0.9315
308.15	0.002	828.1	1572.0	4.7714	1.3332	4.5795	0.9197
	0.004	834.7	1572.0	4.8191	1.3201	4.6002	0.9106
	0.006	835.2	1572.0	4.8451	1.3129	4.6147	0.9057
	0.008	849.9	1554.0	4.8722	1.3207	4.6277	0.9181
	0.01	874.3	1536.0	4.8479	1.3429	4.616	0.9408
313.15	0.002	836.4	1572.0	4.4187	1.4995	4.5841	0.9272
	0.004	838.1	1578.0	4.7917	1.3225	4.5892	0.9193
	0.006	833.5	1584.0	4.7817	1.3207	4.5844	0.9154
	0.008	847.5	1564.0	4.8237	1.3254	4.6045	0.9204
	0.01	872.7	1544.0	4.8066	1.3474	4.5961	0.9503
Diclofenac in 50 % methanol							
303.15	0.002	832.7	1508.0	5.2493	1.2679	4.7817	0.9525
	0.004	834.1	1520.0	5.1705	1.2723	4.7671	0.9543
	0.006	836.6	1532.0	5.0928	1.2816	4.7312	0.9562
	0.008	851.3	1544.0	4.9274	1.3144	4.6537	0.9756
	0.01	868.1	1552.0	4.7824	1.3472	4.5847	0.9965
308.15	0.002	836.4	1516.0	5.2022	1.2679	4.7817	0.9641
	0.004	835.5	1516.0	5.2078	1.2668	4.7843	0.9592
	0.006	835.2	1524.0	5.1551	1.2728	4.76	0.9644
	0.008	849.9	1540.0	4.9612	1.3088	4.6697	0.9848
	0.01	866.7	1564.0	4.7169	1.3555	4.5532	1.0094
313.15	0.002	834.7	1520.0	5.1854	1.2687	4.774	0.9754
	0.004	833.2	1508.0	5.2777	1.2564	4.8063	0.9632
	0.006	833.7	1508.0	5.2745	1.2572	4.8149	0.9716
	0.008	848.1	1538.0	4.9847	1.3043	4.6807	0.9949
	0.01	865.1	1568.0	4.7499	1.3564	4.5691	1.0214

Conted......

Aceclofenac in 10% methanol

303.15	0.002	863.2	1556.0	4.7848	1.3431	4.5859	0.8939
	0.004	894.9	1550.0	4.8124	1.3405	4.5991	0.8945
	0.006	867.3	1544.0	4.7848	1.3391	4.6031	0.8958
	0.008	869.4	1550.0	4.8427	1.3322	4.6136	0.8889
	0.01	851.7	1556.0	4.8494	1.3252	4.6668	0.882
308.15	0.002	862.3	1552.0	4.8145	1.3382	4.6001	0.9004
	0.004	863.7	1554.0	4.7944	1.3421	4.5905	0.9027
	0.006	866.4	1540.0	4.8027	1.3481	4.5774	0.9061
	0.008	868.4	1544.0	4.8867	1.3423	4.6251	0.9073
	0.01	870.8	1576.0	4.7321	1.3408	4.5606	0.8934
313.15	0.002	860.8	1552.0	4.8229	1.3359	4.6073	0.9084
	0.004	862.5	1546.0	4.8508	1.3334	4.6174	0.9090
	0.006	864.7	1540.0	4.8763	1.3316	4.6295	0.9101
	0.008	867.2	1566.0	4.8925	1.3423	4.6372	0.9073
	0.01	869.1	1592.0	4.6465	1.3518	4.5193	0.9037

Aceclofenac in 30% methanol

303.15	0.002	844.8	1576.0	4.7657	1.3314	4.5767	0.9086
	0.004	846.2	1571.0	4.7892	1.3291	4.5881	0.9075
	0.006	847.9	1568.0	4.7969	1.3295	4.5917	0.9089
	0.008	849.7	1534.0	5.0013	1.3304	4.6885	0.9042
	0.01	851.7	1508.0	5.1631	1.2843	4.7651	0.9012
308.15	0.002	844.0	1584.0	4.7222	1.3368	4.5558	0.9402
	0.004	845.1	1565.0	4.8312	1.3225	4.6085	0.9151
	0.006	847.0	1552.0	4.9015	1.3145	4.6415	0.9146
	0.008	848.6	1525.0	5.0671	1.2941	4.7192	0.9111
	0.01	850.8	1492.0	5.2801	1.2693	4.8173	0.9067
313.15	0.002	842.3	1592.0	4.6843	1.3368	4.5375	0.9266
	0.004	844.2	1554.0	4.9051	1.3188	4.6435	0.9212
	0.006	845.3	1552.0	5.1203	1.2848	4.7440	0.9156
	0.008	847.3	1508.0	5.1899	1.2777	4.7761	0.9154
	0.01	849.1	1492.0	5.2908	1.2668	4.8232	0.9141

Aceclofenac in 50 % methanol

303.15	0.002	819.08	1524.0	5.2565	1.2482	4.8066	0.9346
	0.004	823.3	1516.0	5.2849	1.2481	4.8196	0.9377
	0.006	827.6	1500.0	5.3702	1.2414	4.8584	0.9393
	0.008	829.25	1520.0	5.2194	1.2604	4.7897	0.9477
	0.01	830.7	1532.0	5.1291	1.2726	4.7481	0.9495
308.15	0.002	818.2	1536.0	5.1803	1.2567	4.7717	0.9472
	0.004	822.5	1525.0	5.2279	1.2542	4.7935	0.9629
	0.006	826.8	1504.0	5.3469	1.2435	4.8491	0.9505
	0.008	828.4	1508.0	5.3083	1.2492	4.8302	0..9532
	0.01	829.8	1508.0	5.2993	1.2513	4.6262	0.9548

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313.15	0.002	816.6	1552.0	5.0843	1.2673	4.7278	0.9609
	0.004	820.8	1538.0	5.2505	1.2623	4.7557	0.9629
	0.006	825.1	1520.0	5.2457	1.2541	4.8008	0.9642
	0.008	827.2	1500.0	5.3732	1.2407	4.8597	0.9623
	0.01	828.2	1480.0	5.5124	1.2257	4.9222	0.9592

Table 2. Calculated values of hydration number *(S_n)* apparent molar volume *(V_ϕ)*, partial molar volume *($\overline{V}_\phi$)*, solute-solute interaction parameter *(S_v)* of aqueous solution of Diclofenac Sodium and Aceclofenac at T = (303.15, 308.15 and 313.15)K.

T / (K)	m / (mol kg^{-1})	S_n (kgm^{-3})	$V_\phi \times 10^6$ / (m^{3}mol^{-1})	$\overline{V}$ (m^{3}mol^{-1})	S_v / m^3 kg$^{1/2}$ mol^{-3}
Diclofenac in 10 % methanol					
303.15	0.002	883.8	68.31		
	0.004	122.55	41.71	8.41853	
	0.006	1.9514	29.71		
	0.008	62.707	20.61		
	0.01	59.05	11.28		
308.15	0.002	-29.96	68.08		
	0.004	-56.681	43.89		
	0.006	6.1693	31.21	8.12781	0.0541
	0.008	-20.779	21.95		
	0.01	2.04	11.29		
313.15	0.002	-200.88	75.21		
	0.004	-201.26	40.98		
	0.006	4.0435	28.17	8.9679	
	0.008	-119.91	20.61		
	0.01	-63.826	11.22		
Diclofenac in 30 % methanol					
303.15	0.002	82.07	63.99		
	0.004	89.618	34.49	7.4115	
	0.006	1.9514	22.81		
	0.008	63.801	13.84		
	0.01	38.92	8.61		
308.15	0.002	-195.5	63.42		
	0.004	-69.203	35.01		
	0.006	6.1693	22.64	7.5035	0.019
	0.008	-18.848	14.17		
	0.01	-19.899	8.48		
313.15	0.002	-448.27	62.89		
	0.004	-220.26	34.71		
	0.006	4.0435	22.49	7.63089	
	0.008	-220.02	14.16		
	0.01	-81.028	8.36		

Conted......

Diclofenac in 50 % methanol					
303.15	0.002	-710.77	47.56		
	0.004	-401.89	25.43	5.5491	-
	0.006	-258.4	15.14		
	0.008	-290.81	9.23		
	0.01	-259.82	5.14		
308.15	0.002	-1103.31	44.12		
	0.004	-570.11	24.89		
	0.006	--370.11	14.78	5.3764	0.0401
	0.008	-370.13	8.94		
	0.01	-350.77	5.37		
313.15	0.002	-1510.98	43.06		
	0.004	-690.96	24.53		
	0.006	--441.53	14.39	5.057111	
	0.008	-465.66	8.69		
	0.01	-422.35	4.69		
Aceclofenac in 10 % methanol					
303.15	0.002	226.26	72.31		
	0.004	130.16	34.85	8.5891	
	0.006	1.9514	21.91		
	0.008	2.6039	17.07		
	0.01	54.74	15.73		
308.15	0.002	12.493	71.63		
	0.004	-4.5267	34.78		
	0.006	6.1693	21.91	8.5504	-0.006
	0.008	7.8411	17.08		
	0.01	-14.259	15.73		
313.15	0.002	-233.79	71.86		
	0.004	-104.43	34.63		
	0.006	4.0435	21.81	8.5296	
	0.008	7.3161	16.96		
	0.01	-81.928	15.59		
Aceclofenac in 30 % methanol					
303.15	0.002	744.41	64.13		
	0.004	50.926	32.65	7.6108	
	0.006	1.9514	19.96		
	0.008	2.6039	14.60		
	0.01	144.21	11.64		
308.15	0.002	-220.81	63.18		
	0.004	-55.757	32.21		
	0.006	6.1693	19.68	7.52349	0.0021
	0.008	7.8411	14.43		
	0.01	69.992	11.47		

Conted......

313.15	0.002	-5080.51	62.68		
	0.004	-134.34	31.66		
	0.006	4.0435	19.52	7.6214	
	0.008	7.3161	14.24		
	0.01	26.39	11.27		
Aceclofenac in 50% methanol					
303.15	0.002	-607.09	58.29		
	0.004	-304.88	29.98	7.1166	
	0.006	-158.08	17.19		
	0.008	-163.97	12.96		
	0.01	-928.49	10.01		
308.15	0.002	-978.36	56.83		
	0.004	-488.67	29.17		
	0.006	-257.05	16.45	6.9229	0.0341
	0.008	-212.91	12.59		
	0.01	-1054.43	9.64		
313.15	0.002	-1428.39	58.76		
	0.004	-711.17	26.62		
	0.006	-397.74	16.17	7.1557	
	0.008	-278.48	12.26		
	0.01	-1081.85	9.43		

Table 3. Calculated values of solvation number (S_n) apparent molar compressibility (K_ϕ), partial molar compressibility $(\overline{K})$, solute-solute interaction parameter (S_k) of aqueous solution of diclofenac and aceclofenac at T = (303.15, 308.1 and 313.15)K.

T/(K)	m/(mol kg^{-1})	S_n (kgm^{-3})	$K_\phi \times 10^6$/ (m^3mol^{-1})	$\overline{K}$ (m^3mol^{-1})	S_k/m^3 $kg^{1/2}$ $mol^{-3/2}$
Diclofenac in 10 % methanol					
303.15	0.002	334.37	6.1584		
	0.004	122.557	6.0959	6.1587	
	0.006	1.9514	5.9888		
	0.008	62.707	6.0981		
	0.01	59.05	6.1268		
308.15	0.002	-29.96	6.1797		
	0.004	-56.681	6.1939		
	0.006	6.1693	6.1438	6.1575	0.0511
	0.008	-20.779	6.3398		
	0.01	2.04	6.4018		
313.15	0.002	-200.88	6.6579		
	0.004	-201.26	6.6304		
	0.006	4.0435	6.3209	6.3102	
	0.008	-114.91	6.5506		
	0.01	-63.826	6.6566		

Conted......

Diclofenac in 30 % methanol					
303.15	0.002	102.07	6.4881		
	0.004	89.618	6.3071	6.6109	
	0.006	87.256	6.0981		
	0.008	63.801	6.2522		
	0.01	38.92	6.2921		
308.15	0.002	-195.5	6.2814		
	0.004	-69.203	6.3412		
	0.006	-33.194	6.2814	6.7286	0.0211
	0.008	-18.848	6.4889		
	0.01	-19.899	6.5792		
313.15	0.002	-448.27	6.5676		
	0.004	-220.26	6.5798		
	0.006	-140.39	6.6711	6.8141	
	0.008	-220.23	6.6982		
	0.01	-81.028			
Diclofenac in 50 % methanol					
303.15	0.002	-710.77	8.1838		
	0.004	-401.89	8.1431	8.2008	
	0.006	-258.04	7.9293		
	0.008	-290.81	7.8837		
	0.01	-259.82	7.7264		
308.15	0.002	-1103.31	8.5225		
	0.004	-570.11	8.4963		
	0.006	-370.01	8.4362	8.5676	0.0481
	0.008	-370.13	8.3881		
	0.01	-380.77			
313.15	0.002	-1510.98	8.9687		
	0.004	-690.16	9.2681	8.6875	
	0.006	-441.53	9.1121		
	0.008	-465.66	9.2841		
	0.01	-422.35	9.2511		
Aceclofenac in 10 % methanol					
303.15	0.002	226.66	5.3499		
	0.004	130.16	5.3739	5.4876	
	0.006	89.34	5.6362		
	0.008	69.218	5.3762		
	0.01	54.74	5.4239		
		59.05			
308.15	0.002	12.493	5.6171		
	0.004	-4.526	5.6196		
	0.006	-10.184	5.5882	5.7376	0.0381
	0.008	21.281	5.6926		
	0.01	2.04	5.7541		

Conted......

313.15	0.002	-233.79	5.9008	
	0.004	-104.43	5.9635	5.8679
	0.006	-56.625	5.9932	
	0.008	-38.683	6.0148	
	0.01	-81.928	5.6077	

4. CONCLUSION

A detailed analysis of various interaction parameters such as acoustic impedance, intermolecular free length, adiabatic compressibility, relative association, apparent molar volume, partial molar volume, apparent molar adiabatic compressibility, partial molar compressibility, Solvation number of two anti arthritis drug DFS and ACE in methanol medium are calculated from density and speed of sound at a temperature range from 303.15 K to 313.15 K. The apparent molar volume decreases in both DFS & ACE indicating solute-solute interaction. Adiabatic compressibility (β), apparent molar adiabatic compressibility (K_ϕ), Relative association (R_a) increases in ACE but adiabatic compressibility (β), Apparent molar adiabatic compressibility (K_ϕ), relative association (R_a) decreases in DFS. However acoustic impedance of DFS & ACE show opposing trend. The difference in behaviour of ACE & DFS is due to difference in structure and nature of interaction. Both the drug act as structure breaker at low concentration of drug but at higher concentration of drug ACE act as structure breaker but DFS act as structure maker concluding that the drugs under analysis can be characterised as a function of concentration and temperature. Solvation number data and UV-VIS spectra also support the fact that ACE is structure breaker and DFS is structure maker. All the experimental observation show that ion solvent interaction is more in ACE as compared to DFS at higher percentage of methanol.

Calculated acoustic and thermodynamic parameters also support weak drug-solvent interaction in ACE as compared to DFS showing that ACE is a better drug than DFS at lower concentration of a protic solvent like methanol. The result obtained from these studies can thus be helpful for pharmacological application of drug as well as to understand pharmacokinetics process such as transport of drug across biological membranes, drug action and physicochemical properties. As aceclofenac and diclofenac are potent inhibitors of factors known to be involved in the osteoarthritic process, this study showed that in alcoholic medium the reactivity of DFS decreases comparative to ACE due to stronger drug-solvent interaction indicating ACE is a better pain reliever.

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