Making of an effective biological noise barrier to reduce highway noise: a pilot study

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Abstract

Noise pollution has become a major polluting agent in the developing economies. Highway noise pollution has created an environment of stress in people living adjacent to the highways. Various artificial noise barriers available in the market are either costly or requires frequent changes and are not study. This excess noise causes various physical and mental ailments in the local populace. The aim of the study was to find a cheap, sturdy and biological origin noise barrier which can be easily deployed. Vetiver (Chrysopogon zizanioides) is a bunchgrass native to India, these grass are sturdy, and have potential to be an effective noise barrier. 4 such sites on highways were selected. 2 sites were made control and other 2 were made the experimental sites. Control sites did not have the grass cover whereas the experimental sites were given the grass coverage. Anthropometric, nutritional, fasting blood sugar, cortisol and blood pressure of volunteers selected were recorded and analysed. It was observed that the vetiver grass had the tendency to reduce the noise level. The volunteers on experimental sites showed reduced fasting blood sugar, cortisol and blood pressure levels. Serum insulin levels increased after 3 months of experimentation. Basic anxiety inventory data showed significant reduced anxiety in volunteers in the experimental site. In India vetiver grass due to its easy availability and health benefits the grass has lot of potential to be used as effective noise bio barrier.

Keywords: Noise pollution, Stress, Physiology, Vetiber, Biological noise barrier.

Introduction

Noise can be defined as unwanted sound characterized by the intensity, frequency, periodicity (continuous or intermittent) and duration of sound. A prominent feature of the modern day environment exposure to high level of noise disturbs physical and mental well-being of a person. Studies in laboratory rats have shown that noise can cause stress and change of behaviour with increase in corticosterone levels but very few studies have been performed in open fields with human subjects[1]. Studies that have been performed concluded that noise interferes in task performance, modifies social behaviour and causes anxiety and annoyance. The effects of noise on human health are divided into four groups; they are i. Physical effects ii. Physiological effects such as increased blood pressure, irregularity of heart rhythms, increased blood sugar iii. Psychological effects such as sleeplessness, going to sleep late, irritability, annoyance and stress and iv. Effects on work performance[2].

Rapid advancement of our economy warranted buildings of highways connecting every major economic corridor. While that certainly gave impetus to the economic scenario, it also gave rise to noise pollution in those areas. There is also a general agreement that exposure for more than 8 hours to sound levels in excess of 85 dB is potentially hazardous; to place this in context, 85 dB is roughly equivalent to the noise of heavy truck traffic on a busy road. Vehicular traffic and the noise generated by the passing of heavy vehicles can cause increased blood pressure, anxiety, insomnia, stress etc[3, 4].

Noise barrier is any obstruction created in between the highway and the household which will reduce the level of noise reaching the inhabitants. Noise barriers can be applied to existing or planned transportation projects. They will probably be an effective weapon to reduce sound levels in adjacent lands. Constructions of barriers along the road, construction of walls with sound proofing materials are very good methods of noise barriers but at the same time are costly[5].

Vetiver (*Chrysopogon zizanioides*) is a perennial bunchgrass of the Poaceae family, native to India. Vetiver can grow up to 5 feet high and form clumps as wide. The stems are tall and the leaves are long, thin, and rather rigid. These grasses found throughout India and easy to cultivate has many uses as soil and water conservation, herbal skin care uses etc[6]. Our aim in this study is to find out whether these grasses can act as effective sound barrier and whether it can act as a cost effective

biological noise filter by monitoring the parameters such as blood pressure, insomnia etc.

Material and methods

Site selection: Chinsurah Mogra CD Block of Hoogly district village near National Highway 2 was selected as the test site. We found houses on both sides of the highway. Moreover, the clusters of houses on one side were at a distance of 400 meters site A (control) from the highways and 760 meters site B on the other side. Another site one kilometre East of the control site was chosen as the experimental site, the cluster of houses and their distance from the highway was same as the control site.

Description of site: Chinsurah Mogra CD Block is bounded by Pandua and Balagarh CD Blocks, in the north, Chakdaha CD Block, in Nadia district across the Hooghly the east, Sreerampur Uttarpara CD Block in the south and Polba Dadpur CD Block in the west. Chinsura-Mogra CD Block has an area of 54.87 km^2. Chinsurah Magrapanchayat samity has 10 gram panchayats. The block has 30 inhabited villages. Gram panchayats of Chinsurah Mogra block / panchayat samiti are: Bandel, Chandrahati I, Chandrahati II, Debanandapur, Digsui-Hoera, Kodalia I, Kodalia II, Mogra I, Mogra II and Saptagram. The first wave of industrialisation came with the establishment of jute mills along the banks of the Hooghly River long back in the British era. The district has moved from an overwhelmingly rural society with a mere 14.92% of the population living in urban areas in 1901 to a more urban society with 33.47% of the population living in urban areas in 2001. In the rural areas of the district while 14.95% of the total workers were cultivators, agricultural labourers were 24.31%, thereby indicating the huge pressure on land that outstrips its ownership.

Volunteer selection: Detailed surveys of area on both sides were conducted. Initial healthy (males and females) adult volunteers (25-45 years of age) numbering 426 from site A (control and experimental) and 438 from site B (control and experimental) were selected. On the volunteers few exclusion criteria was placed, i. Addiction, ii. Established medical reason for insomnia iii. Malignancy, iv. Neurodegenerative diseases, v. Temporary residency, vi. Lack of interest in the study vi. Housing condition. The houses in which the test volunteers lived were made up of bricks and were of 5-6 inches thick. The trend was uniform in all the test subject houses. The layout of the houses on both side were uniform and not scattered as such houses would have differential access and exposure of noise.

After a thorough check up only 100 people each from site A (control), site A (experimental) and 100 people each from site B (control), site B (experimental) were confirmed for the study (randomly). In each of the sites 10 people were selected apart from the study volunteers, who will monitor the study (LAs or local agents) under the guidance of the research team. 40 people were selected who were provided the training and supplied with the instruments to collect the data at the four study sites, from the volunteers at 15days duration.

Choice of land and Vetiver cultivation: Vetiver (*Chrysopogon zizanioides*) was procured from Assam's lower Barak valley. Permission for the study was sought from the local panchayat and was granted. The ground was prepared that was lying immediate next to the highway. A total of 500 meters in length and 6 meters width area was cultivated on both sides of the highway at two sites. Grasses were planted and allowed to grow for 90 days. The planting commenced from the month of July and from mid-September the plants have grown to a height of 4.5 feet and form clumps in width. The entire area of the cultivated grasses was covered with net to prevent any unwanted animals straying in the local human habitats. The entire setup was sprayed with anti-insecticides or insect repellents.

The root system of vetiver is finely structured and very strong. Our pilot study elsewhere shows it may grow 3 metres (10 ft) to 4 metres (13 ft) deep within the first year after given nutrient through vermicompost and lime water spraying fortnightly. An indigenous treatment with the use of *panchagabba* (comprising of 20 litres of cow urine, 7 kg of moist cow dung, 5 litres of milk, water from 6 coconuts, 500 g of *ghee*, 24 bannas are thoroughly mixed and churned by a mixer-grinnder) 4 times a year keep abundance growth and keep the plant green. The vetiver plant is highly drought-tolerant and can help to protect soil against sheet erosion. Vetiver was planted in long, neat rows across the slope for easy mechanical harvesting. Trenches are 15 centimeters (6 in) to 20 centimeters (8 in) deep. Sandy loam nursery beds was used to ensure easy harvest and minimal damage. Weed control during establishment phase is done by using atrazine after planting. To control termite, neem based products are used.
Duration of study: 90 days

Research Protocol: An initial stakeholder meeting was arranged with local administration, local agents, volunteers and research team. Mode of communicability, mobile numbers, and network connectivity established. Protocol of study was explained in vernacular, written were consent obtained. Steps as laid down by ICMR was discussed and ensured. Institutional ethical committee was approached and permission obtained (AARC/02/16). Stakeholders meeting is being planned every fortnight and daily monitor by local agents. An initial survey in respect to populace in the area in respect to the socio-economic-cultural-political habitats, religious approaches and regular food intake, condition of houses, daily physical activities, drug history, personal aptitudes. An initial anthropometrical, nutritional, clinical and biochemical assessment was done and validated (Table-2). At about duration of 15 days each, measurements were made and the parameters studied were sound intensity, blood pressure, fasting blood glucose levels were measured. Apart from these subjects were studied on their

anxiety levels, sleeping duration, stress coping skills. Survey of symptoms points to reduction of biasness for accuracy[7].

Equipment used: Sound intensity was measured with Digital Sound Level Meter (Lutron 30-130db SL-4012), blood pressure by Accumed BP monitor, fasting blood glucose by Accucheck Aviva plus and semi auto analyser (Boehringer). The entire experiment was continued for 3 months starting from middle of September to December. Psychometric scales with subjective evaluation by clinicians were done for stress, anxiety etc, sleep assessment was done by seven-question Insomnia Severity Index.

In order to observe the effect of composite on the volunteers' blood samples were tested for FBS, TC, HDLC by using Photometer 4010 of Boehringer, Germany. VLDLC is being computed as 1/5th of TG value and LDLC is being computed by the difference TC - (VLDLC + HDLC). Serum insulin and cortisol levels were measured by ELISA method using Genetix, ELISA plate reader.

Evaluation of the blood parameters: Blood samples were drawn by professionals without the knowledge of the study, to reduce biasness as per the standard precautionary norms. Samples were labeled and sent to lab with proper precaution. Biochemical assessments did include total cholesterol (TC), high density lipoprotein cholesterol (HDLC), low density lipoprotein cholesterol (LDLC), very low density lipoprotein cholesterol (VLDLC), triglycerides (TG) and fasting blood sugar (FBS) and was done by standard methods as depicted by Boehringer and by reagents supplied to meet the standard quality at monthly intervals by an indwelling catheter placed in the anti-cubital vein. Serum insulin and cortisol level was measured. Raw data were validated statistically using SPSS version 19.

Results and discussion

Statistical analyses: Results were statistically analysed through SPSS software version 9 and final results were obtained.

Table-1: Detailed surveys of area.

	Site A (control)	Site A (experiment)	Site B (control)	Site B (experiment)
The result of survey in respect to Strongly religious and stubborn	12%	11%	10%	11%
Moderate follower	64%	63%	65%	62%
Mildly follow or not at all	24%	26%	25%	28%
Economic conditions				
APL	47%	47%	48%	49%
BPL	25%	25%	25%	26%
Not in the lists	28%	28%	27%	25%
Social approaches: (Modernity scale)				
Traditional	14%	13%	14%	14%
Modern	62%	62%	61%	62%
Transitional	24%	25%	25%	24%
Like present day school concept and education	96%	97%	97%	96%
No comments	4%	3%	3%	4%
Percentage of literates	96%	97%	97%	96%
Dietary history				
Carbohydrate	70-80%	71-80%	70-80%	72-80%
Fat	10-15%	10-14%	10-15%	10-13%
Protein	10-15%	10-15%	10-15%	10-15%
Vegetarians	11%	12%	14%	13%
Avoid red meat	32%	33%	34%	35%

	Site A (control)	Site A (experiment)	Site B (control)	Site B (experiment)
Disease records				
Type 2 diabetes	17	19	21	18
Hypertension	51	50	51	49
CAD	5	4	5	5
Past history of Jaundice	27	27	27	27
Amoebiosis and Giardiasis	142	140	139	143
Renal disorders	5	6	7	9
Locus of Control				
External	74%	75%	74%	75%
Internal	26%	25%	26%	25%
House Conditions				
Pucca house	94%	93%	94%	94%
Kuccha house	6%	7%	6%	6%

Table-2: Anthropometrical, biochemical, nutritional and clinical data in both experimental and control groups of human volunteers at four sites (n=400) (The values are expressed as mean ± SD).

Parameters		Experimental Group	Control Group
Age		25-45 years	25-45 years
Sex	Male	54	47
	Female	46	53
Body Mass Index		22.8±1.2 Kg/m^2	22.6±1.6 Kg/m^2
Nutritional status	Mild (67%)	73%	
	Moderate (7%)	8%	
	Severe (nil)	0%	
Systolic Blood Pressure		118±7 (mm of Hg)	120±8 (mm of Hg)
Diastolic Blood Pressure		75±6 (mm of Hg)	80±6 (mm of Hg)
TC		146±10(mg/dl)	152±11mg/dl
LDLC		87±6mg/dl	86±9mg/dl
HDLC		33±7mg/dl	35±4mg/dl
VLDLC		25±5mg/dl	28±3mg/dl
TG		116±9mg/dl	144±19mg/dl
Serum Bilrubin		0.6±0.2 mg/dl	0.5±0.3 mg/dl
Hemoglobin Percentage		12.03±0.4 gm%	12.6±0.4 gm%
SGPT		36±5.4 iu/l	35±7.0 iu/dl
Blood Urea		23±6.2 mg/dl	24±5.8 mg/dl
Serum Creatinine		1.0±0.4 mg/dl	1.±0.6 mg/dl
Serum Uric Acid		4.2±1.2 mg/dl	4.4±1.5 mg/dl
FBS		108±8 mg/dl	109±7 mg/dl

Site A (control): 80% are employed in agri-oriented works, 12% on business, 4% in government and private jobs and rest are having no fix jobs. Warm infestations: 92 (Round worm76, Hook warm 15, Tape worm 2).

Site A (experimental): 82% are employed in agri-oriented works, 14% on business, 4% in government and private jobs and rest are having no fix jobs. Warm infestations: 90 (Round worm75, Hook warm 15, Tape worm 0).

Site B (control): 82% are employed in agri-oriented works, 12% on business, 4% in government and private jobs and rest are having no fix jobs. Warm infestations: 89 (Round worm74, Hook warm 4, Tape worm 15).

Site B (experimental): 77% are employed in agri-oriented works, 13% on business, 6% in government and private jobs and rest are having no fix jobs. Warm infestations: 91 (Round worm76, Hook warm 14, Tape worm 1).

The above data reveals biochemical, nutritional and clinical data of the volunteers and it show a tendency towards Type 2 diabetes like other rural areas of Bengal. Most of them are malnourished due to improper dietary education and nutritional training.

Survey reveals that rural the area had composite development, house through Indira Abash Yojona, flow of education, comprehensive knowledge of surroundings and modern approaches. Society is cosmopolitan, secular, open and free minded and believes in God. They are tolerant, believes in their local leader and strong familial bonding. Computer and internet access is there and society leaps forward to cashless education, e-commerce, e-health etc. They want deep and strong Governmental efforts in the direction.

Sound level before and after cultivation of vetiver (3 months). At the time of experiment ambient temperature is between 27-35°C and relative humidity <80.

Table-3a: Sound level measurement (400 metres).

Time (months)	Vetiver height (metres)	Sound level (dB)	
		control	experimental
0	0	100.46±5.12	100.46±6.92
1	0.22	100.32± 4.37	98.32± 5.37
2	0.61	99.02± 5.02	93.02± 4.02*
3	1.37	98.26± 4.43	85.26± 4.13*

Sound requires a medium to flow and in this case it is obviously air. From the table it is clear vetiver height has got a relationship with reduction in sound level ($p= 0.04$). The exact reason of

reduction of sound in 1 month remains speculative may be due to clumpy nature of the plant.

Table-3b: Sound level measurement (760 metres).

Time (months)	Vetiver height (metres)	Sound level (dB)	
		control	experimental
0	0	98.16±4.33	98.16±3.33
1	0.22	99.46± 4.06	95.46± 3.02
2	0.61	98.54± 2.80	91.54± 2.88*
3	1.37	99.86± 4.38	82.86± 2.33*

As being expected with increasing distance sound intensity reduces, however similar experiment done in dry season show different results and the result thus obtained may be due to combined effect of humidity and rainfall.

Effect on desired blood parameter during the experimentation is shown in Table-4a and b.
Age-specific data analysis in both the experimental and control groups showed no significant variations with ages and therefore data in both groups were analyzed as a whole. In addition, no significant effects of gender were observed.

Table-4 shows that sound reduction reduces the blood glucose, lipid values and serum insulin level, possibly by inducing a peaceful sleep, sound mind and less stress and cortisone reduction.

Basic anxiety inventory (BAI) was done[8,9].

Results showed that volunteers are in moderate to severe level of anxiety in site A and it was reduced from mild to moderate and in site B volunteers are in mild to moderate range which was reduced to mild range, only prevailing changing factor is reduction in sound level due to this biologic filter(10)($p=0.04$).

Stress: To measure stress level we use Depression Anxiety Stress Scale 42.

The score varies in depression 16±2, anxiety 14± 3, stress 24±4(Site A), obviously in moderate to severe range; in site B depression 11± 4, anxiety 12± 4, stress 16± 3 and it is within mild to moderate range. After experiment it becomes in depression 13±2, anxiety 11± 3, stress 16±4 (Site A) (mild to moderate), and depression 9± 2, anxiety 10± 2, stress 14± 3 (site B) (normal to mild);the effects is due to reduction in sound level ($p=0.05$).

Reaction to stressful situations is influenced by many factors, including relevant personality characteristics, and the degree of stress experienced. The manner in which one copes depends on sound stressors on physiological responses influencing health outcomes[11,12].

In our study volunteers complained of Sleep deprivation (Site A) and on being compared with Site B it shows that sleep deprivation as claimed does not affect motor or majority of cognitive functions, reasons unknown. Village dwellers particularly the volunteers are actively working in fields due to farming activities and possibly the physical stress allows the requisite sleep of the person and hence it is not reflected in any scale and no burnout symptoms exists[9, 13].

Serum cortisol measurement: Early morning fasting sample drawn by professionals who had no knowledge of the test (to reduce biasness) under adequate protection in volunteers who are in rest for the last 24 hours and not consuming any cortisol or glucocorticoid containing drugs, no sex steroids, no oral contraceptives, no anti-seizure drugs. Similarly blood pressure

was monitored and recorded. In both cases the reduction may be due to change in stress level due to reduction in sound intensity.

The reduction is due to decreased sound intensity.

Study in diabetic volunteers: Noise leads to increased blood sugar level due to increased stress[4,10]. The research team had found detected diabetic cases (Type 2) in 22 volunteers. Their blood sugar values were tested and analysed statistically in total and also as a separate group, to find an insight to the effects of noise reduction in blood sugar control before and after experiment and for that purpose 22 diabetic patients were chosen at random in nearby area as control. The result is shown in Table-7.

Table-4a: Effects of sound reduction by vetiver on BBP (TC, HDLC, LDLC, VLDLC and TG) in experimental and control group of volunteers.

Time (Month)	Group	TC mg/dl	HDLC mg/dl	LDLC mg/dl	VLDLC mg/dl	TG mg/dl
First	Control	152±11	35±4	86±9	28±3	144±19
	Experimental	146±10	33±7	87±6	25±5	116±9
Second	Control	154±14	37±8	87±10	28±3	144±12
	Experimental	142±15	34±8	84±6	23±3	110±16
Third	Control	153±14	37±8	85±10	29±4	147±8
	Experimental	140±14	42±8*	82±7*	20±6*	106±8*

The values are expressed as mean ± SD, * indicates statistical significance ($p<0.05$).

Table-4b: Effects of sound reduction by vetiver on Fasting Serum Insulin Values (pmol/l) in experimental and control groups.

Time (Month)	Experimental group	Control group
First	40±3.2	42±2.6
Second	43±4.2	43±2.8
Third	45±3.4*	43±2.8

The values are expressed as mean ± SD, * indicates statistical significance ($p<0.05$).

Table-5: Shows the anxiety levels before and after the experiment.

Site	Anxiety Level before experiment	Anxiety Level after experiment
Site A (control)	31± 7	30± 5
Site A (experimental)	29± 5	24±3*
Site B (control)	32±7	33±6
Site B (experimental)	29±3	23±4*

The values are expressed as mean ± SD, * indicates statistical significance ($p<0.05$).

Table-6: Serum cortisol measurement.

Site	Serum cortisol (mcg/dL)	Blood pressure (mm of Hg)	
		Systolic	Diastolic
Site A (control)	25±4	156±8	96±8
Site A (experimental)	22±3	136±6*	82±6*
Site B (control)	23±2	143±7	91±5
Site B (experimental)	21±3	146±3	79±4*

Table-7: Effects in fasting blood sugar in selective volunteer before and after study.

Time (Month)	Experimental group	Control group
First	152±15 mg/dl	152±11mg/dl
Second	147± 12 mg/dl *	153±15mg/dll
Third	134±10mg/dl *	153±12 mg/dl

The values are expressed as mean ± SD, * indicates statistical significance (p<0.05).

The result showed that noise reduction by vetiver reduced fasting blood sugar level.

Conclusion

Highway noise is a single most important pollution source in parts of rural India It has been linked with lack of sleep, anxiety, lack of concentration, poor stress coping skills etc. Among its other non-auditory effects include cardiovascular risks, endocrine disruption, cognition etc. Also in a country like India with little infrastructural capability we have to create cost effective solution to our problems. Vetiver a variety of grass has the potential to provide such cost effective solution to our highways noise pollution problems. The subject initially showed signs of stress with poor stress coping capability, a rise in blood pressure and blood sugar levels. The subjects also suffered from lack of sleep, annoyance. After creating a barrier with vetiver and 3 months of experimentation we found that there was significant decrease of blood pressure levels with slight decrease in the blood glucose levels. The test subjects also showed increase in the time of sleep and better stress coping skills than the beginning of time. The sound measured after the growth of vetiver showed that the grass can effectively reduce the sound levels by effective blocking it. The noise that was reaching the habitation was much lower than previously recorded.The effect was more pronounced in the site B where the habitation was at farther from the highway. Among the two sites site B showed better improvements among all the parameters in the test

subjects. It may also be stated with time growth of vetiver increases in length and breadth and becomes further effective.

Thus noise barriers using vegetation such as vetiver can act as cost effective biological noise filtering agent.

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