Research on road traffic noise and human health in India: Review of literature from 1991 to current

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Published
2012

Journal Title
Noise and Health

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http://www.noiseandhealth.org/text.asp?2012/14/58/113/97255
Research on road traffic noise and human health in India: Review of literature from 1991 to current

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Abstract
This article reviews the literature on research conducted during the last two decades on traffic noise impacts in India. Road traffic noise studies in India are fewer and restricted only to the metropolitan areas. The studies over the years have also focused on the monitoring, recording, analysis, modeling, and to some extent mapping related themes. Negligible studies are observed in areas of physiological and sleep research exposure–effect context. Most impact studies have been associated with annoyance and attitudinal surveys only. Little scientific literature exists related to effects of traffic noise on human physiology in the Indian context. The findings of this review search and analysis observe that very little studies are available relating to traffic noise and health impacts. All of them are subjective response studies and only a small portion of them quantify the exposure–effect chain and model the noise index with annoyance. The review of papers showed that road traffic noise is a cause for annoyance to a variety of degree among the respondents. A generalization of impacts and meta-analysis was not possible due to variability of the study designs and outputs preferred.

Keywords: Attitudinal survey, exposure–effect study, noise pollution, road traffic noise, subjective response, systematic review

Introduction
With growth and urbanization of our cities and towns, there has been a rapid increase in the traffic volume on the roadways. Although transportation is an indispensable part of the modern society, its benefits may be overshadowed by its negativities and is a cause for concern for the community. Noise pollution from road traffic streams is one such negative consequence. During the past decade, the understanding that it is an increasingly serious risk has gained ever wider recognition, mostly due to the fact that noise is a very complex phenomenon not only in its physical aspect but also in its psychological and medical dimensions.[1,2] The extent of the environmental noise situation has also been highlighted by the World Health Organization,[2,3] with identifying the fact that impacts such as community annoyance, dissatisfaction, interference with communication, sleep disturbance, impaired task performance, auditory, physiological, and other health issues have resulted from this. Noise also has significant impact on the quality of life. Such impacts are seldom catastrophic and are often only transitory, but adverse effects can be cumulative with prolonged, continuous, or repeated exposure. Consequently, it is practically indispensable to monitor, predict, and analyze noise and evaluate the exposure–effect mechanism of it. During the last century, substantial research has been conducted to study road traffic noise exposure and human response, annoyance, discomfort, and sleep disruption. Most part of them have used the monitoring, modeling, and/or other assessment methodologies including the socioacoustical surveys and sleep disturbance studies in laboratory and field types.[4-7]

In the Indian perspective, like everywhere, road traffic noise is unique in comparison to the other pollutants, because unlike air or water pollution, noise has no residual evidence to serve as a continuing reminder of its unpleasantness. Even though its effects usually severe as any other pollutant, noise is often regarded with the lowest priority for control and management. Road traffic although is a very significant part of the urban environment, but it is also the major source of urban noise emission. The growing number of vehicles emit more unrestrained noise pollution and associated health effects that can cause both short-term as well as long-term psychological and physiological disorders. The most probable effects that can be perceived by the population to be directly caused by road traffic noise are “sleep disturbance” (associated with nighttime noise) and “communication disturbance” (associated with day time noise). Most of the community, especially in the Indian subcontinent, is
not aware that noise can cause any health damages and in contrast, studies globally, has provided significant evidence that environmental noise and especially road traffic-generated sound has severe negative impact on human health.

Currently, limited research exists on the exposure–effect studies of road traffic noise in the Indian scenario, with most reporting the noise quality only. In view of this, the present review study is intended with the objectives of conducting a thorough systematic review and possible meta-analysis of the identified research papers during the last 20 years in India. The importance of this article is that it will put in prospective the traffic noise research scenario to a larger and international audience and also bring together some of the quality literature and state of the art for the Indian researchers. This type of review on the topic is not reported and may be of aid in the current and upcoming investigations on this theme. This article would be a novel type, giving a glimpse of the traffic noise–effect research in India till present date and would provide a background for current and future researchers.

Methods

To evaluate the traffic noise situation in India and how various researchers have studied its effects on human health, a review of the literature from the last 20 years (1991 to current) was conducted in line with the methods proposed by Omlin et al. The study used methods of “string search” in search engines, “database search” (SCOPUS, Elsevier, Springer, Taylor Francis, PubMed, Google scholar, etc.), “conference proceedings search” (ICBEN, Euronoise, Internoise, et c.), and “author’s library search.” String searches included sets of terms, namely “road traffic,” “noise pollution,” “road traffic noise,” “transportation noise,” “road traffic noise and human health,” “sleep disturbance,” “annoyance,” “road traffic noise modeling,” “traffic noise mapping,” and “traffic noise impact assessment.”

All the relevant and identified articles and papers were read in full and used for information extraction and stored in the database with details of publication particulars, study location, period, approach, and methodology for assessing noise exposure, sampling, results of exposure–effect, and major conclusion. For evaluation of the quality of the studies considered, the format of Omlin et al. has been used with some modifications to suit the review purpose and objective. Criteria adopted to assess the quality of the studies considered included the following:

- a. Study population is well defined (age, gender, and number)
- b. Exposure is well defined (location and duration of noise measurement or presentation)
- c. Declaration of statistical methods used
- d. Sample size: small ($n \leq 50$), medium ($n > 50 \leq 200$) and large ($n > 200$)
- e. Random sample selection
- f. Exposure effect curve

Results and Discussion

Literature search relating to the topic of interest yielded 17 articles, which included two conference proceedings and 15 journal articles (one article from author’s own publication). Table 1 shows the details of the studies identified and included for this review, whereas Table 2 gives the overall quality of the articles based on the criterias. The approach, outcomes, and quality assessment of the articles reviewed are discussed below.

Main results

Rao and Rao carried out noise pollution studies and community survey in the city of Visakhapatnam (1991–1992). Noise levels and subjective measurements were recorded in different localities; correlation of annoyance using mean dissatisfaction score (MDS) with 198 traffic noise was studied and predictions were made. Subjective response to noise exposure obtained on a 7-point scale of dissatisfaction was correlated with the measured $L_{eq}$ and $L_{dn}$ data. The authors concluded that values predicted from the regression equations were found to be far more reliable compared with those obtained from other studies done previously.

Chakraborty et al. reported the status of road traffic noise and community response in Calcutta metropolis in terms of seasonal basis (1998). Based on the annoyance survey, regression association of noise parameters and percent of highly annoyed population were developed along with MDS predictions and it was reported that 30% of the subjects were highly annoyed with traffic noise, and models of noise and annoyance were highly correlated.

Mohan et al. studied traffic noise and community response of inhabitants living in close proximity to an arterial road in New Delhi (2000). The study reported that people living up to the distance of 30 m from the road are much annoyed due to traffic. Residents living in all the floors in multistoried apartments were also annoyed to different degrees. About 70% of those surveyed were ready to shift houses and move away from the road, irrespective of the current facilities.

Ingle and Pachpande conducted a community survey on traffic noise among residents of Jalgaon city (2005). The result of the audiometric study undertaken showed mild hearing impairment in both the target group (exposed and unexposed) population. Moderate hearing loss was reported in high number in subjects from the exposed group of residence. It was observed that the self-reported hearing loss using the screening questions and rating scale were moderately good measure of hearing impairment in comparison to audiometric assessment. It was reported that 81% of those surveyed...
were affected by noise from highway in comparison to the unexposed group (61%). It was concluded that the exposure of the population to higher noise levels had affected the hearing capability in the area. No exposure–effect curves were reported.

Pachpande et al.[14] conducted assessment of hearing loss among school teachers and students exposed to highway traffic near Jalgaon city (2005). Noise quality assessment based on the self-reported hearing status data and audiometric analysis revealed that about 84% teachers and 92% students, among those surveyed, reported hearing difficulty in the questionnaire. In the audiometric testing, mild hearing loss, in range of 25–35 dBHL, was reported in both the subject groups. It was concluded that strategies need to be adopted for protection of the teachers and students from the noise exposure were very essential.

Tripathi and Tiwari[16] reported attitude of traffic personal toward transportation noise in a study in Ahmedabad (2006). No traffic noise monitoring was reported for this study. The questionnaire included questions regarding the self-assessment of the policemen about their hearing ability, past and present exposure to loud sound, and the use of personal protective devices such as earplugs and earmuffs. Of those surveyed, 11.6% complained of regular tinnitus, while 62.8% had work-related tinnitus and experienced it during working hours only. It was reported that self-assessed

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### Table 1: Studies investigating exposure–effect of road traffic noise in the Indian scenario from 1991 to current

<table>
<thead>
<tr>
<th>Author</th>
<th>Location (city/province)</th>
<th>Type of study</th>
<th>Data source</th>
<th>Noise measurement/presentation</th>
<th>Measurement of effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rao et al.[9]</td>
<td>Vishakapatnam, Andhra Pradesh</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>Yes</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Rao et al.[10]</td>
<td>Vishakapatnam, Andhra Pradesh</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>Yes</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Rao et al.[11]</td>
<td>Vishakapatnam, Andhra Pradesh</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>Yes</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Chakraborty et al.[12]</td>
<td>Kolkata, West Bengal</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>Yes</td>
<td>Questionnaire, audiometry</td>
</tr>
<tr>
<td>Mohan et al.[13]</td>
<td>New Delhi</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>Yes</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Ingle et al.[14]</td>
<td>Jalgaon, Maharashtra</td>
<td>Field, Survey</td>
<td>Conference proceeding</td>
<td>Measurement done. Not reported</td>
<td>Questionnaire, audiometry</td>
</tr>
<tr>
<td>Pachpande et al.[15]</td>
<td>Jalgaon, Maharashtra</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>Not reported</td>
<td>Questionnaire, audiometry</td>
</tr>
<tr>
<td>Tripathi et al.[16]</td>
<td>Ahmedabad, Gujarat</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>No measurement</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Banerjee et al.[17]</td>
<td>Asansol, West Bengal</td>
<td>Field, Survey</td>
<td>Own library</td>
<td>Yes</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Nandanwar et al.[18]</td>
<td>Nagpur, Maharashtra</td>
<td>Field, Survey</td>
<td>Conference proceeding</td>
<td>No measurement</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Agarwal et al.[19]</td>
<td>Jaipur, Rajasthan</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>Yes</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Goswami et al.[20]</td>
<td>Balasore, Orissa</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>Yes</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Mishra et al.[21]</td>
<td>New Delhi</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>Yes</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Wani et al.[22]</td>
<td>Gwalior, Madhya Pradesh</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>Yes</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Agarwal et al.[23]</td>
<td>Jaipur, Rajasthan</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>Yes</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Goswami et al.[24]</td>
<td>Balasore, Orissa</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>Yes</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>Patil et al.[25]</td>
<td>Amravati, Maharashtra</td>
<td>Field, Survey</td>
<td>Journal article</td>
<td>No measurement</td>
<td>Questionnaire</td>
</tr>
</tbody>
</table>

### Table 2: Quality of individual studies considered for evaluation the exposure–effect due to road traffic noise reported in Indian literature from 1991 to current

<table>
<thead>
<tr>
<th>Author</th>
<th>Study population well defined</th>
<th>Exposure is well defined</th>
<th>Declaration of statistical methods</th>
<th>Sample size</th>
<th>Random sample selection</th>
<th>Exposure effect studies/curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rao et al.[9]</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Large (n=1195)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Rao et al.[10]</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Large (n=1195)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Rao et al.[11]</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Large (n=1195)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Chakraborty et al.[12]</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Large (n=1100)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Mohan et al.[13]</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Medium (n=175)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Ingle et al.[14]</td>
<td>No reported</td>
<td>No</td>
<td>No</td>
<td>Not reported</td>
<td>School teachers and Students</td>
<td>Yes including audiometric</td>
</tr>
<tr>
<td>Pachpande et al.[15]</td>
<td>No reported</td>
<td>No</td>
<td>No</td>
<td>Not reported</td>
<td>Traffic police</td>
<td>No</td>
</tr>
<tr>
<td>Tripathi et al.[16]</td>
<td>No reported</td>
<td>No</td>
<td>No</td>
<td>Medium (n=86)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Banerjee et al.[17]</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Large (n=869)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Nandanwar et al.[18]</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Large (n=378)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Agarwal et al.[19]</td>
<td>Not reported</td>
<td>Yes</td>
<td>Yes</td>
<td>Large (n=450)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Goswami et al.[20]</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Large (n=212)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Mishra et al.[21]</td>
<td>Not reported</td>
<td>Yes</td>
<td>Yes</td>
<td>Large (n=350)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Wani et al.[22]</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Medium (n=100)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Agarwal et al.[23]</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Large (n=550)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Goswami et al.[24]</td>
<td>Not reported</td>
<td>Yes</td>
<td>No</td>
<td>Medium (n=136)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Patil et al.[25]</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Large (n=500)</td>
<td>School, shopkeepers</td>
<td>No</td>
</tr>
</tbody>
</table>

1 Small (n≤50), medium (n>50≤200) and large (n>200)
prevalence of reduced hearing was found only in two (2.3%) subjects.

Banerjee et al.\cite{Banerjee2008} conducted a study to evaluate road traffic noise impact on the local community of Asansol city (2008). Relationship between traffic noise levels and annoyance was studied using correlation, linear, and multiple linear regression analyses. It was observed that the mean value of percent of population highly annoyed (%HA) due to road traffic noise was 26.50 ± 3.37 (19.44–33.2), whereas the MDS was 2.96 ± 0.90 (1.04–4.45). It was observed that noise index-based models provided better annoyance predictions in comparison to vehicular input based models. The only two direct impacts that they were to relate to traffic noise pollution were speech interference during the day and sleep disturbance during night.

Nandanwar et al.\cite{Nandanwar2009} studied the effect of traffic noise on the quality of life among residents around the major road intersections in Nagpur city (2009). Majority of the subjects expressed annoyance due to traffic noise during daily activities, and of these 29% were extremely, 24% very much, 22% to some extent, and 19% little annoyed. 33% of subjects reported more annoyance during evening than daytime. No exposure–effect curve was reported for this study. Most identified causes due to traffic noise were headache, nervousness, and hearing problems. The authors concluded that both income and education positively affected the perceived impact of traffic noise on health-related variables.

Agarwal and Swami\cite{Agarwal2011} studied the correlation between annoyance level and different noise indices along selected roadways in Jaipur city (2009). In this study, to define the noise annoyance quantitatively, a new point scale of MDS was used. A set of regression equations were developed between mean noise index (L_{eq}, L_{10}, L_{max}, L_{dn}, and TNI) and percentage of the person highly annoyed and MDS. It was observed that among the subjects, the reported percent HA ranged between 17.07% and 39.69%. It was concluded that a strong correlation existed between percentage highly annoyed and various noise indices.

Goswami\cite{Goswami2008} studied traffic noise in terms of standard noise indices, community response, and community health effects in Balasore city (2009). It was reported that 63% respondents were not satisfied with the noise level in their dwellings. Of the different sources of environmental noise, the most significant was identified as road traffic, with 49% of respondents reported being highly annoyed by the road traffic stream. 28% of subjects reported sleep disruption due to nighttime movement of vehicles.

Mishra et al.\cite{Mishra2010} reported traffic noise along a rapid bus transit corridor in Delhi city (2010). On the basis of the study, relationship between different noise parameters and annoyance level was quantified using linear and multiple regressions. It was observed that 68% of the subjects reported the problem of stress due to traffic noise exposure. No exposure–annoyance curves were reported. The subjects identified hearing loss (64%), blood pressure (56%), depression (48%), agitation (36%), and fatigue (12%).

Wani and Jaiswal\cite{Wani2010} studied traffic noise and subjective community response in the Gwalior city (2010). Based on a questionnaire survey, it was reported that 50% of the subjects were always annoyed and 33% had a constant headache. For speech interference, 43% subjects reported highly affected, 21% moderately affected, 32% low, and 4% least affected.

Agarwal and Swami\cite{Agarwal2011} studied the impact of noise pollution on residents dwelling near roadside in Jaipur city (2011). The degree of annoyance was assessed by means of a questionnaire and it was reported that road traffic was the major source of noise in the area. Results of a health survey reported about 52% of subjects were suffering from frequent irritation, 46% had hypertension, and 48.6% reported difficulties in sleep due to traffic noise and that female subjects were more sensitive toward noise-related health problems. It was explained that in India the numbers of housewives are higher than the working-class females and due to continuous living in a particular surrounding they have to face noise-related problems daily.

Goswami et al.\cite{Goswami2008} studied traffic noise levels along a road connecting two university campuses in Balasore city (2011). It was reported that the source of noise along the study area was predominantly due to vehicular traffic with heavy vehicles being the major emitters. The survey identified that the majority of the subjects, including drivers, expressed their dissatisfaction over the increasing intensity of noise in the area. The study reports that headache, bad temper, hearing problem, and loss of concentration were some of the significant effects due to high noise levels. About 86% of students reported that their study was disturbed by frequent air horns and 21% had sleep disruption nighttime traffic noise.

Patil et al.\cite{Patil2011} reported subjective analysis on traffic noise and the quality of life among residents around the major arterials roads in Amravati city (2011). It was reported that majority of the subjects were aware of the interference of traffic noise with daily activities and impact on health. It was observed that 16.8% were extremely and 21.1% were very much annoyed due to vehicle noise. Reported maximum annoyance (47%) was highest during the midday and afternoon, while 50% of subjects reported headache, nervousness, and hearing difficulties due to exposure to noise.

This review cautiously observes that only limited number of studies on the exposure–effect of road traffic have been conducted in India during this period, with the survey-based approach being the preferred method of evaluating vehicle noise and health impacts. Studies reporting audiometric test
outputs were limited to three. The studies reported were of short term with traffic noise levels been recorded near the subject habitat to estimate the exposure condition.

Researches using methods of sleep study using polysomnography have not been reported, although similar studies have been documented during the last 20 years in the international scenario.[4-6]

The studies involved
This review article discusses that the Indian researchers have analyzed the problem of road traffic noise and human health impacts, in terms of variations or similarity in methodological approach and reporting of the dose–response situation. The quality of the reviewed articles in light of the criteria’s selected for these studies are detailed in Table 2. It was observed from this review that in 70% of these studies, the study population (age, gender, and number) was well defined, where as in 61% cases the noise exposure pattern, including locations, sampling, duration, and presentation of data, was observed. The reporting of the statistical methods and outputs was used by 35% of the researchers. The studies varied in terms of the sample size used for the subjective evaluations and it was observed that only medium (n > 50) and large (n > 200) samples were used, with samples size not less than 50 reported.

The application of statistical tools to analyze the data from the reviewed papers was not possible because of the small number of paper identified with the relevant topic and also the variability in them in terms of approach and reporting of outputs.

It is observed that 73% of the articles reported using large sample, which is statistically better, and in 76% cases, the approach of random sampling of subjects was used. In the rest, particular group of persons (like those spending 14–16 hours at home) or people from different professions (students, teachers, traffic personals, or shopkeepers) exposed to traffic noise were selected, thus in these cases the results may not be representative of the entire community in the study area. The important aspects of these studies were the evaluation of the traffic noise exposure–effect state, which would have been the anticipated end product of these researches and would also have provided a better criterion for comparison among the articles considered. Only in 7 studies out of the 17 (41%), exposure–effect relationship was reported, and the annoyance (%HA and or MDS) was curve plotted against a suitable noise parameter (Leq, Ldn, etc.) to developed models. Among the rest of the articles, three did not provide any curve, although assessment was conducted. Here reporting was limited to the estimation of the correlation coefficient among the noise–attitude parameters. The residual 41% articles reported details of subjective response data using the questionnaire tool.

Conclusions
Overall, this review, a first of its kind in terms of traffic noise exposure–effect in India, would be a concise and critical article for current and future researchers and acousticians. It puts together 20 years of research (1991 to current) on the topic of road traffic noise and how its exposure–effect relationship has been evaluated by various researchers. This study provides qualitative aspects of the papers reviewed and would aid as a guideline for future research. Although the paper had been limited due to publication bias,[8] i.e., there are chances that many papers have been left out, if they have not been published in journals or conferences or not reported at all.

Based on the articles reviewed for this study, it may be cautiously observed and concluded that it is not possible to generalize the trend of this research theme and combine the outputs of results, although they address the same hypothesis of traffic noise effects on human health; in this systematic review, the identified studies were much wide ranging in terms of their sample size, exposure data presentation, randomness of sampling, and/or exposure–effect output; the overall study design and approaches varied across the articles considered; the low number of the studies identified to be considered for this review, over a considerable period of 20 years and does not allow a meta-analysis of the data derived through this review. Overall, the generalization to the population under study is not possible; from the focal hypothesis of the present review article regarding the effect of traffic noise on human health, it can be concluded that the local population may be disturbed due to traffic noise, in a greater or lesser way, although no generalization can be done due to the limited number of articles identified. The correlation models reported by the articles would prove useful in predicting the annoyance and in turn the human health to a certain degree.

Acknowledgment
The author wishes to thank Prof. Alan Lex Brown and the URP, Griffith School of Environment, Griffith University, Australia, for providing permission to use facilities to publish this article.

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How to cite this article: Banerjee D. Research on road traffic noise and human health in India: Review of literature from 1991 to current. Noise Health 2012;14:113-8.

Source of Support: Nil, Conflict of Interest: None declared.