

# The role of acoustics in building clean urban and architectural environment

Hence, this article was devoted towards presentation of research outcomes on pursuit for 'cleaner' and higher quality of sound environment in everyday city, in order to create safer and more ergonomic permanent, day-to-day living conditions.

Climate changes, influencing whole human life and strongly affecting all built environment, cannot be discussed without taking into account sound field factors, which are understood as a part of ergonomics and microclimate, especially since the noise exposure is already treated as pollution [1]. Quality of living, working and recreating is connected to the urban, building, and architectural acoustical performance [2]. Though European legislation has noticed and addressed this problem a long time ago, i.e.: Environmental Noise Directive [3], all the time new acoustical standards are being introduced into the trade of architects and urban planners. It is only recent, that selected norms have become a valid part of building code regulations, just to recall Polish Norm PN-B-02151-2 [4], concerning noise protection in rooms, set in 2018 (replaced old one from 1987). Legislation activity in this manner proves, that the noise pollution problem in Europe is substantial.

Thus, design world of architecture and urban space needs to follow these new requirements, sometimes change work approach and in effect pay more attention towards proper and intentional solving of built environment. All these actions must be taken in a way to create optimal sound field conditions for users, reflecting new city-planning models, aiming at decreasing overall pollution.

## Aim and method

In contemporary architectural and urban design, a huge amount of attention is paid towards important issues of users' safety, fire protection, structural demands, energy savings and others, which is reflected i.e. in building codes, standards and regulations. It seems that still less attention is paid towards acoustic conditions, which can be visible



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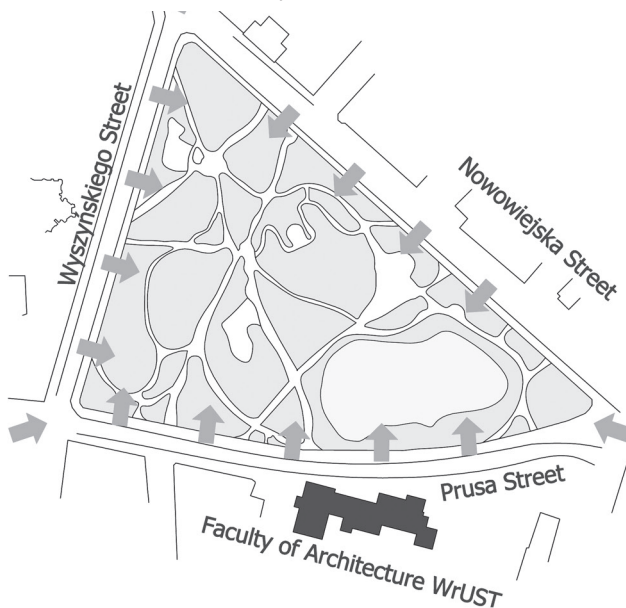
in sound produced by daily city traffic, air movement above residential estates, flat-to-flat sound transition in massively erected developer housing, illegible speech in conference rooms and universities' auditoria or loud public health care buildings and schools, in which users find nervousness and anxiety.

Hence, this article presents the start-up research on threats and problems of contemporary noise pollution in urban and architectural environment, in close relation to the design methods, issues, and matters. Thus, the main purpose is to present elaborated set of general guidelines for architects and urban planner, which can be easily followed and used in everyday practice. Secondary aim of elaboration is to show regular sound level conditions, in a day-to-day city residents situations, both indoor and outdoor and to evaluate whether a certain architectural or urban solutions are efficient in lowering human exposition on the noise pollutions in contemporary city.

The main research method was cooperative analysis showing normative standards and requirements; and actual studies and measurements, presented in reliable recourses (based on literature review). The next step was to set out in which day-to-day situations people are experiencing proper acoustic conditions and which are more dangerous. In this way a general set of guidelines for designers, could be set, that allow creating safer residential conditions in urbanized areas.

These indicators are concluding the following article, with the proviso that these are only preliminary research results that will be expanded in further studies. One of the necessary limitations, was omitting of a detailed study on Reverberation Time in interiors. This specific issue has appeared in previous articles and will be further explored for next publications.

II. 2. The Park of Stanisław Tolpa in Wrocław with access of traffic noise [photo. and elab. by author, elab. on the basis of GoogleMaps].



## Recommendations and threats

Firstly, a desirable model of acoustical parameters for human being had to be set out. Aforementioned Polish Standard PN-B-02151-2 [4] defines requirements on permissible sound level in rooms designated for people stay and meant for different purposes, starting from residential and finishing at public buildings. It focuses on noise, which can be created by different technical devices and utilities inside of the building or in its proximity (also service premises, i.e. restaurant, dancing clubs). Just to give an example, for single, multi-family, but also patient rooms, the permissible model sustainable sound level A is 25 dB and model maximal sound level is 30 dB. In school classrooms and teachers rooms (also lecture rooms at universities), the permissible model sustainable sound level A, should not exceed 35 dB. The universities laboratories, without devices emitting acoustical distortions, this parameter should not be over 40 dB, and for offices – 35 dB, while for open office plan – 40 dB. The highest values are allowed inside the swimming pools and sports halls – 50 dB [4].

These requirements have been established on the basis of studies on a human perception of sound field, in a room or outside. According to sources [5–7] sound level depending on frequency ranging from 35 to 70 dB affects human sleep, relaxation process in disadvantages way, while level around 80 dB and higher can cause damage of hearing, disorder of blood circulation, balance or activity of nervous system, also cardio-vascular disease, internal organs vibration and nausea. Exposition for so called “threshold of feeling” [5] or at occasions named “threshold of pain” levels 110–130 dB (depending on frequency and capabilities of individuals), on which ear-drum membrane may burst, can cause permanent damage to the organism and finally death. It should be highlighted, that if dangerous exposition occurs – i.e. in factory environment – it cannot be too long and always proper equipment (hearing protecting) and procedures (suitable medical examinations) must be followed – i.e. a document recalled by Everest and Pohlmann [5], who refer back to Occupational Noise Exposure by the Occupational Safety and Health Administration (OSHA).

A quotation from European Environment Agency, [8, pp. 2], seems to sum up this passage very clearly: “Noise affects people physiologically and psychologically: noise levels above 40 dB LAeq2 can influence well-being, with most people being moderately annoyed at 50 dB LAeq and seriously annoyed at 55 dB LAeq. Levels above 65 dB LAeq are detrimental to health (WHO, 2000).”

## Exemplary daily environments

Knowing threats and recommendations, there must be analyzed examples of actual sound level in specific places and certain situations, characteristics for city residents daily life. European Environment Agency, [8, pp. 1], in document from 1999 stated that: “About 120 million people in the EU (...) are exposed to road traffic noise levels above 55 Ldn dB. More than 50 million people are exposed to noise levels above 65 Ldn dB”, and these are a general data. It can be also expected, that a lot of these problems deepened since 1999 in a number of European counties. Taking closer look into the details – i.e. provided by acoustic maps of selected cities – show that depending on a location, parameters of traffic noise exposition may be much higher.

On emission acoustic map of Wrocław (Poland) [9] can be seen, that for example at the Faculty of Architecture Wrocław University of Technology LDWN is 65-70 dB in front of the building (same for immission) and 60-65 dB behind the building (immission there is below 55 dB), same goes for small city park by the Faculty – The Park of Stanisław Tolpa, where 65-70 dB is near roads surrounding the park and 60-65 dB values inside the park (it is the same for immission). The LN is 60-65 dB in front of the aforementioned building (same for immission) and 55-60 dB behind it (and immission is below 55 dB), with similar outcomes in the recalled park, except immission is lower for LN parameter. It is worth mentioning, that The Park of Stanisław Tolpa is surrounded by streets from all sides, and The Wyszyńskiego Street is espe-

cially loud. Reaching out to the residential areas just across the Tolpy Park, we can state that immission parameters are much more favorable inside of the courtyard of the typical XIX/XX century dense and massive houses. Summing up, it would be advisable to close windows in the Faculty building during traffic rush hours, in order to provide students with better studying conditions, while their rest during daytime, would be advisable inside of the tenement houses courtyards, than in Tolpy Park. Moreover, this data show, that during students day-to-day activities (crossing the roads, trying to relax in the park, opening the classroom window), they are exposed to loud sound field, which can affect, i.e. with nervousness or problems with concentration.

Around the main Market Square in the Old City center, which together with several streets around is pedestrian area only, the emission road noise LDWN at main communication roads ranges between 70-75 dB – same for immission map, the road noise LN generally drops down 60-65 dB (same for immission), and on the Market Square itself the road noise LDWN measures 55-65 dB (it is below 55 dB for immission), while the road noise LN ranges between 50-55 dB (it is below 55 dB for immission). These conditions are being experienced not only by the residents of Wrocław's Old Town, but by all, who want to stay around the Market Square

Also, our interiors can become quite inconvenient to the consumers. Everyday use appliances like, hairdryer or vacuum cleaner (depending on a model) emits noise at levels 70-80 dB and during a school break on the corridor 100 dB can be experienced [8]. For example a shopping mall with occupancy equivalent sound level of noise penetrating the room from all noise sources together LAeq between 67 and 70 dB (studies carried out in Portugal in objects of an area between 2,000–72,000 m<sup>2</sup>) [10].

Comparing these numbers towards recommendations, it can be stated that urban day-to-day environment is polluted with noise. Yet, not only quietness of an environment is an important factor in understanding the quality of the outdoor or indoor acoustical field. For example, bird singing in the park or delicate water-flowing humming is perceived as beneficial to the relaxation and resting process of the human being. Therefore, it is crucial to create space, in which such phenomena can be heard.

## Conclusions – recommendations

To sum up paying attention in the urban, building, architectural and interior design to acoustic parameters of sound, will highly increase the overall well-being outdoor and indoor of inhabitants. Thus, will positively affect overall investments costs, human health and will substantially decrease need for medication production and needs for therapeutic services, which is now growing rapidly and so far, continually.

In light of aforementioned consideration, for external city environment, a following recommendations have been set (please note, that these are general highlights):

- advised limitation of traffic in city centers, downtowns, historic urban areas,
- recommended limitation of speed for cars in residential zones,
- recommended limitation of speed for cars under and over ground parking and garages,
- exclusion of cities from inter-city and international traffic (advised are: beltways, highway beltways in distance to the urban fiber),
- recreation city greenery set in courtyards of estates, distanced from the main traffic and acoustically sheltered by buildings, will provide more peaceful areas, than squares by main roads and their crossings,
- settling large-surface greenery areas in the cities and preserving the existing (i.e. vegetation urban farming lots)
- airtight buildings with properly solved heat insulations, will provide quieter living and working conditions,
- door and windows with frames must be selected suitably – i.e. according to the acoustic maps or actual acoustic measurements – to prevent sound transitions from outside to the inside,





Il. 2. Quintet urban interiors with pleasant natural sounds – recreation city plaza and Watergate estate (both in Washington D.C.) [photo. by Author].

- design of the building solutions, like walls, slabs, wraths, partitions, joints, installation openings, electric boxes, according to building acoustic guidelines,
- design of interiors with recommendations of room acoustics, with control of reverberation time – i.e. volume and geometry planning, use of sound absorbing materials in ceilings, flooring, furniture, placing acoustic systems,
- selection of quiet, certified appliances and devices, like ventilation, lifts, escalators, air-conditioning and removing of old and used – not only for rooms for human stay but also technical and service spaces (i.e. parking lots and garages).

What is interesting a lot of these recommendations are advised for limitation of air pollution in the city and pursuit for more energy-saving environment. Paying attention to climate changes, need for decreasing of environment pollution and reduction of resources uses, comes together with attempts aiming at reduction of noise pollution and raising of beneficial acoustical phenomena in built environment. It does not mean, that types of design must be changed or totally transformed – i.e. not to use open spaces plans or not to allow cars into the cities. But the overall process has to be much more conscious and purposeful, than a traditional one and it must be adjusted to acoustical requirements outside and inside.

The continuation of this work assumes caring out a long-term measurement with a team of acousticians containing a set of day-to-day situations in selected architectural and urban spaces, aiming at creating a follow up more detailed guidelines.

#### Literature

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#### CORRECT METHOD OF QUOTATION

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**Abstract:** Built environment of Polish cities, both external and internal is polluted not only with chemical and physical harmful particles, but also with a number of diversified, continuous sounds, which may in substantial way negatively affect psychological and physical well-being of humans. Moreover, in extreme situations sound may damage vital organs of organisms and at daily occasions negative exposure may cause a number of problems in a longer time perspective. Noise produced by traffic, loudness of school brakes, shouts and car-horns, humming of air condition devices and ducts, air traffic, plus many more, are exposing city users not only on shorter or longer hearing losses, but also on vibration of internal organs and raising of overall anxiety. At the same time, cities are also filled with positive sounds, which allow to lower the blood pressure, calm and relax residents, like: birds singing, leaves and rain humming, water floating, and so on. Hence, this article was devoted towards presentation of research outcomes on pursuit for 'cleaner' and higher quality of sound environment in everyday city, in order to create safer and more ergonomic permanent, day-to-day living conditions.

**Keywords:** architectural acoustics, building acoustics, urban acoustics, built environment, ergonomics.

**Streszczenie:** ROLA AKUSTYKI W BUDOWANIU CZYSTEGO ŚRODOWISKA ARCHITEKTONICZNEGO I URBANISTYCZNEGO DLA CZŁOWIEKA. Zbudowane środowisko polskich miast, zarówno zewnętrzne, jak i wewnętrzne, jest zanieczyszczone nie tylko szkodliwymi cząstkami chemicznymi i fizycznymi, ale także szeregiem zróżnicowanych dźwięków, które w istotny sposób mogą negatywnie wpłynąć na dobrostan psychiczny człowieka. Co więcej, w ekstremalnych sytuacjach dźwięk może fizycznie uszkodzić ważne organy organizmu, a w warunkach codziennych negatywna stała, choć niewielka ekspozycja może powodować wiele problemów zdrowotnych, rozwijających się w dłuższej perspektywie czasowej. Hałas powodowany przez ruch, głośność przerw szkolnych, buczenie urządzeń klimatyzacyjnych i wiele innych, naraża mieszkańców miasta nie tylko na krótko- lub długoterminowe ubytki słuchu, ale także na wibracje narządów wewnętrznych i wzrost ogólnego niepokoju. Jednocześnie miasta są również wypełnione korzystnymi dźwiękami, które pozwalają obniżyć ciśnienie krwi, uspokoić i zrelaksować mieszkańców, takimi jak: śpiew ptaków, szum liści i deszczu, przepływanie wody itp. Ten artykuł został poświęcony prezentacji wyników badań dotyczących dążenia do czystszej i wyższej jakości środowiska dźwiękowego we współczesnym mieście w celu stworzenia stałych, bezpieczniejszych i bardziej ergonomicznych codziennych warunków życia.

**Słowa kluczowe:** akustyka architektoniczna, akustyka budowlana, akustyka miejska, środowisko ludzkie, środowisko zabudowane, ergonomia