Environmental acoustics - what, for what and why?

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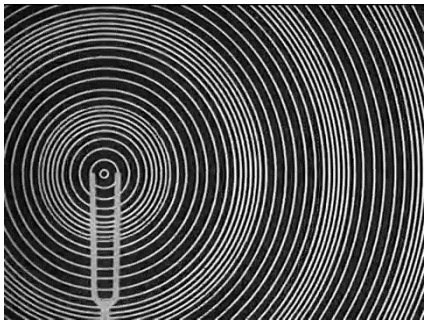
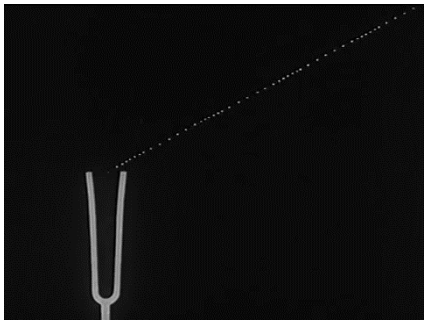
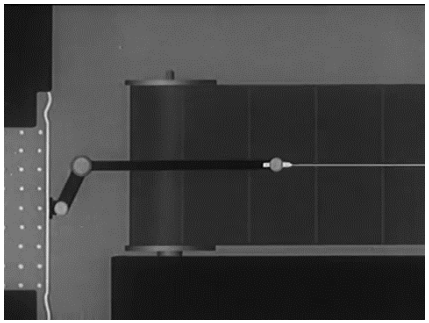
Introduction

- What is noise?
- Sources of sound
- Environmental acoustics
  - Research areas
  - Basic principles
  - Targets for acoustic analysis
  - Identification methods
  - Selection of solutions
- A broader view - connections with other areas

What is noise?

Sound definition:

In physics, **sound is a vibration** that typically propagates as an audible wave of pressure, through a transmission medium such as a gas, liquid or solid. (Wikipedia)

Sound Waves and their Sources (1933) – youtube.com

Noise definition:

Noise is unwanted sound judged to be unpleasant, loud or disruptive to hearing. From a physics standpoint, noise is indistinguishable from sound, as both are vibrations through a medium, such as air or water. The difference arises when the brain receives and perceives a sound (Wikiepdia)

What does that mean?
What is unwanted sound?
What does it mean that something is loud?

What is noise?

WHO - health outcomes associated with environmental noise

Critical health outcome	Important health outcome
Cardiovascular disease	Adverse birth outcomes
Annoyance[7]	Quality of life, well-being and mental health
Effects on sleep	Metabolic outcomes
Cognitive impairment	
Hearing impairment and tinnitus	

We have several areas where noise has been studied and described in detail.

In the case of **environmental noise**, the basis for the assessment is the **sound level measured outdoors** at the place of human presence.

The permissible noise levels have been determined for different noise sources, **depending on their nuisance**.

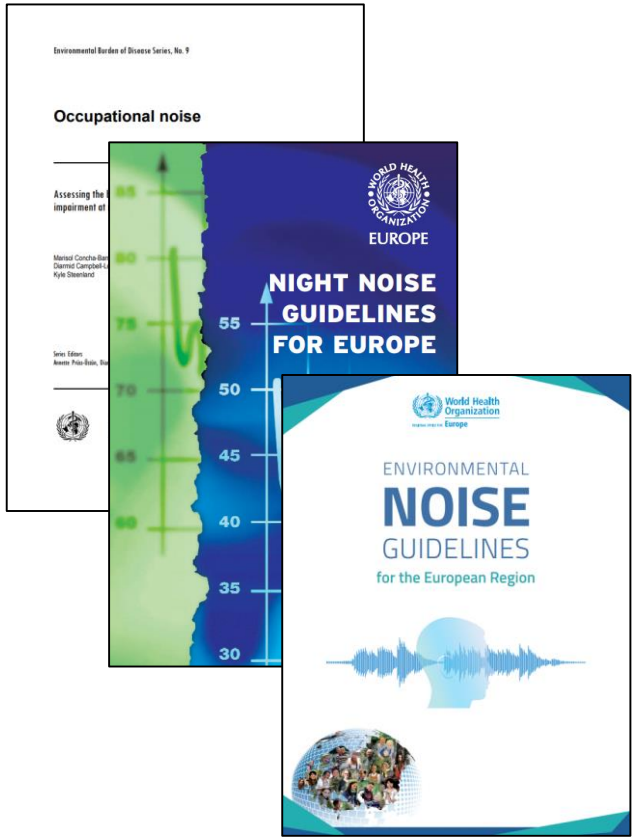
In each country, assessment standards are **described in law**.

A good starting point for assessment is the **WHO recommendations**, which are based on multiple sources.

In another area, noise assessment at workstations is different. There, the assessment is based on levels that cause hearing loss.

NOISE LEVELS - WHO RECOMENDADTION		
SOURCE	**LDEN**	**LNIGHT**
ROAD	53	45
RAIL	54	44
AIRCRAFT	45	40
WIND TURBINE	45	-
PLANTS	50	45

LDEN - Day-evening-night-weighted sound pressure level as defined in section 3.6.4 of ISO 1996-1:2016
LNIGHT - Equivalent continuous sound pressure level when the reference time interval is the night – ISO 1996-1:2016



WHO documents

Sources of sound

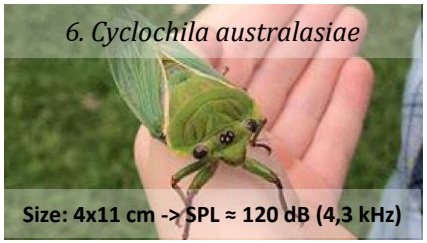
Natural (made whitout human activity)

- Animals (birds, frog, wild animals)
- Wind
- Sea/Water waves
- Tree rustle
- Volcanoes

Wind greater than 5 m/s makes it impossible to measure.

The noise of trees in light wind can raise the level to 60 dB and prevent correct noise assessment.

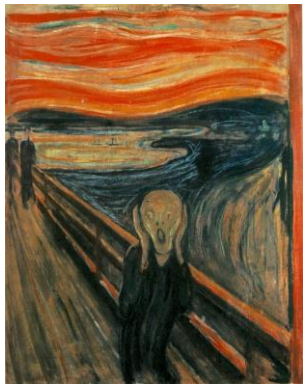
Animals:



In the evening, in summer, the measurement is disturbed by crickets, which in Poland emit noise at the level of 50 dB.
In the morning, spring and summer, the measurement is disturbed by birds which emit noise at the level of 50 - 80 dB.

During a storm, the noise level can rise to 50 dB

The Krakatau volcano eruption of 1883 was heard from a distance of 3200 km. The sound wave circulated the earth several times.



"Screaming" Edvard Munch was created 10 years later in 1893

Most of these sources are interfering with the measurement of environmental noise.

Sources of sound

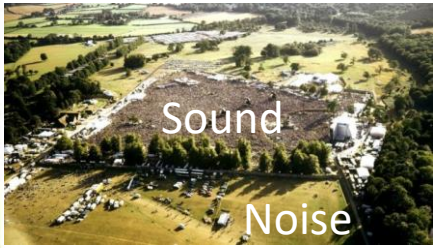
Anthropogenic (made by human activity)

- Music intsruments,
- Neighbourhood noise,
- Recreational noise
- Road traffic
- Railway traffic
- Aircraft traffic
- Industrial plants (machines, fans, chemical processes, flows, other)
- Animals (farm animals)

Main area of environmental noise

Atlantic City Convention Hall in New Jersey (USA) - Largest organ - 32,000 pipes, weight 150 tons

Sometimes neighbours' noise is more nuisance than other sources.



Recreational noise should be analysed for each activity.

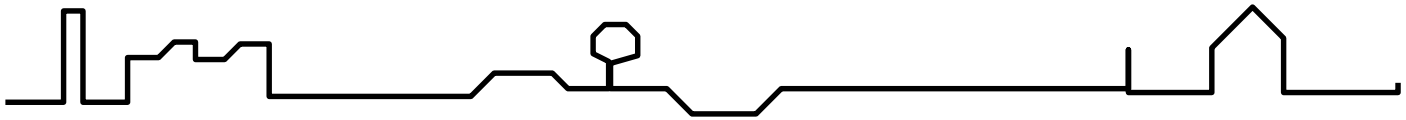
Can you tell us which sources work when I measure environmental noise?

I know how to measure noise, but how to count cars?

I know how to measure noise, but how do I automatically recognize what kind of train it is?

We are making aircraft quieter and quieter, but the increase in traffic is so great that the noise is still growing.

Environmental acoustics – research areas



Source

- how and why sources emit noise?
- how to measure the sound power level and emision sound?
- how to model a source?

Propagation

- what and how does it affect sound propagation?
- how to measure the state and stability of the atmosphere?
- how to model sound propagation?

Immision

- how to determine dominant noise sources?
- how noise affects people?
- what assessment indicators should I use?

Environmental acoustics – basic principles

Point source

- *Sound power level - LW [dB]*
- *Spectrum*
- *Directivity*
- *localization*

Propagation

- *Distance [m]*
- *Temperature [^{0}C]*
- *Humidity [%]*
- *Favourable conditions [%] – based on the meteorological statistic*
- *Ground factor (porous or hard)*
- *Obstaclaes / Bariers*
- *Vegetation (forests)*

Reciver

- *Sound level – L_{pA} [dB]*
- *Localization*
- *Distance to facade*

MAIN FORMULA:

$$L_{pA} = L_{WA} + 20\log(d) + A_{atm} + A_{gr} + A_{bar} + A_{misc}$$

- $20\log(d)$: 6dB/dd
- A_{atm}: „eat" high frequency
- A_{gr}: typical reduce: 0 – 3 dB
- A_{bar}: one major reflection near source + 3 dB; screening by acoustic screen 5 dB (half screen) + 1,5dB/1m
- A_{misc}: typical green don't shield noise

amendments to the propagation phenomena

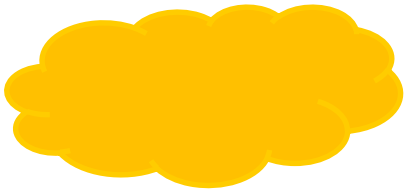
Environmental acoustics – basic principles

Point source | Propagation | Reciver

L_{W1} = 100 dB

L_{W2} = 100 dB

L_{W3} = 103 dB



Distance: 100 m
Attenuation: 40 dB

Lp = 66 dB

FORMULA:

$$L_{pA} = 10\log(10^{(0,1*(LW1-40)} + 10^{(0,1*(LW2-40)} + 10^{(0,1*(LW2-40)})$$

Each doubling of sources with the same impact is + 3 dB.

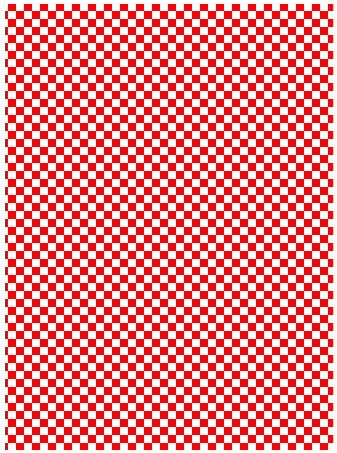
Environmental acoustics – basic principles

Area with
1000 point sources

Propagation

Reciver

L_{Wx} = 60 dB



Distance: 1000 m
Attenuation: 60 dB

Lp = 30 dB

(Lp from 1 source = 0 dB)

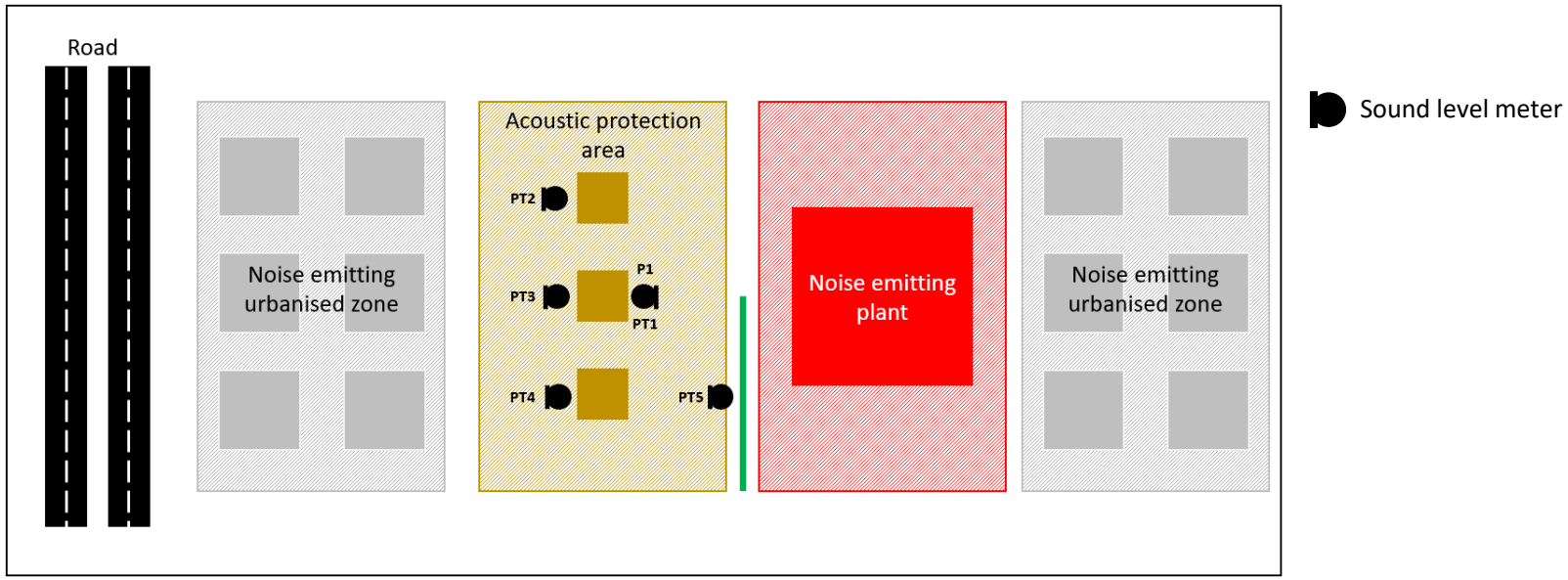
FORMULA:

$$L_{pA} = 10\log(10^{(0,1*(LW1-40))}) + 10\log(N)$$

Impact of 1000 quiet sources of noise can cause noise exceeding.

Environmental acoustics – targers for acoustic analysis

- Impact assessment in the existing state



Task:

- Determine the operating modes of the establishment
- Select a place for evaluation
- Select a measurement methodology
- Perform measurements
- Prepare a report

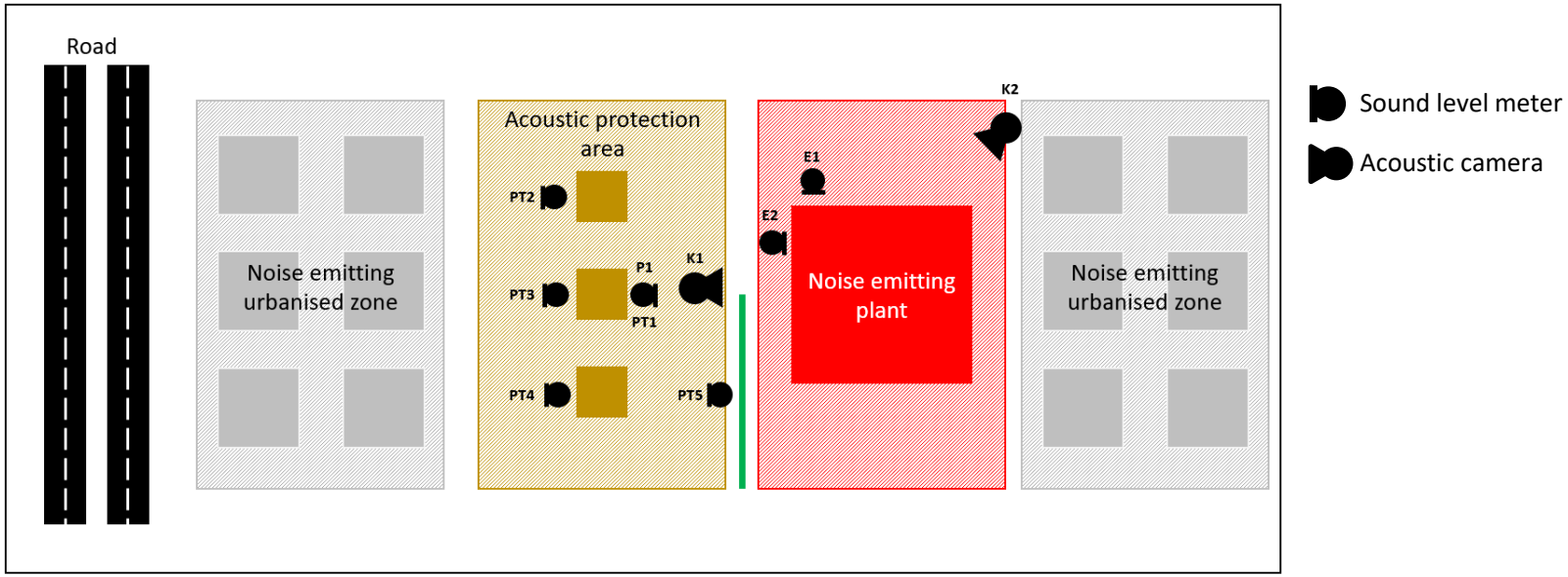
Comments:

Basic measurement, to determine the noise level and exceedance

On the basis of this measurement it is rarely possible to indicate further actions.

Environmental acoustics – targers for acoustic analysis

- Indication of the principal place of emission



Task:

- Determine the operating modes of the establishment
- Select a place for evaluation
- *Selection of measurement locations with an acoustic camera*
- *Determination of the measurement methodology*
- Perform measurements
- Prepare a report
- Sometimes: Development of a basic acoustic model

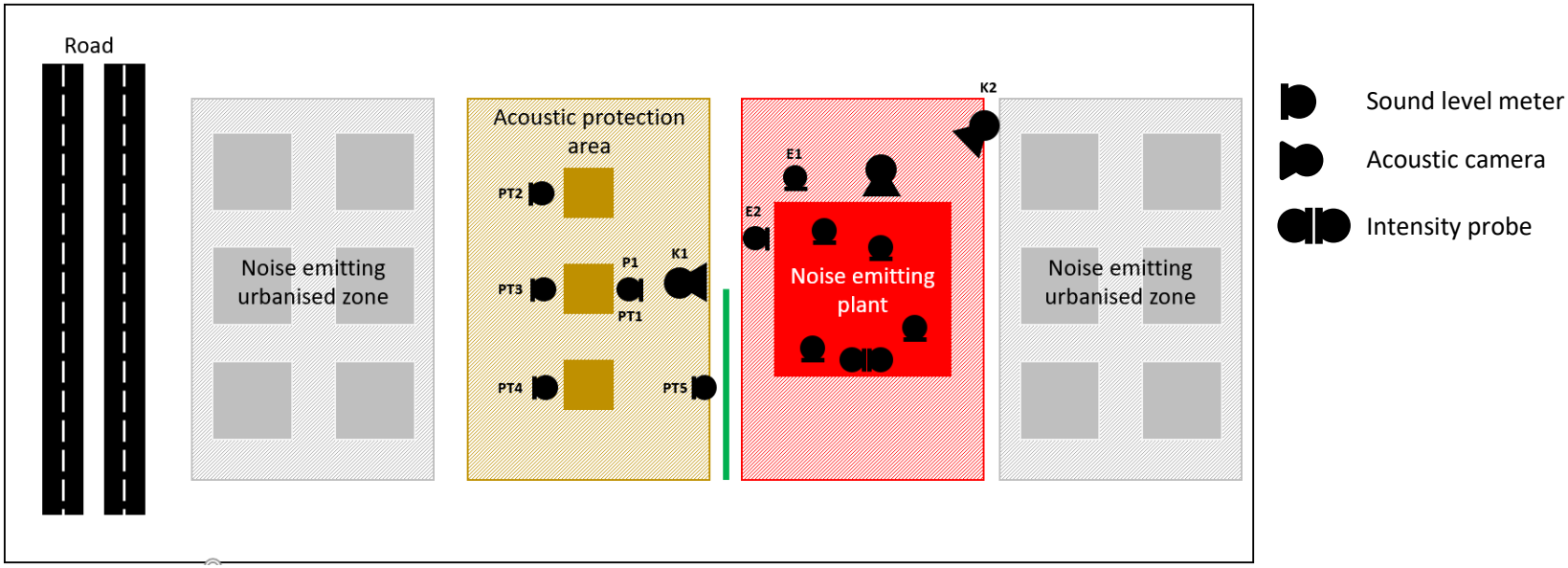
Comments:

Extended measurement to take account of noise levels, exceedances and locations for detailed analysis.

Based on this measurement, it is sometimes possible to identify actions.

Environmental acoustics – targers for acoustic analysis

- Development of a noise reduction strategy



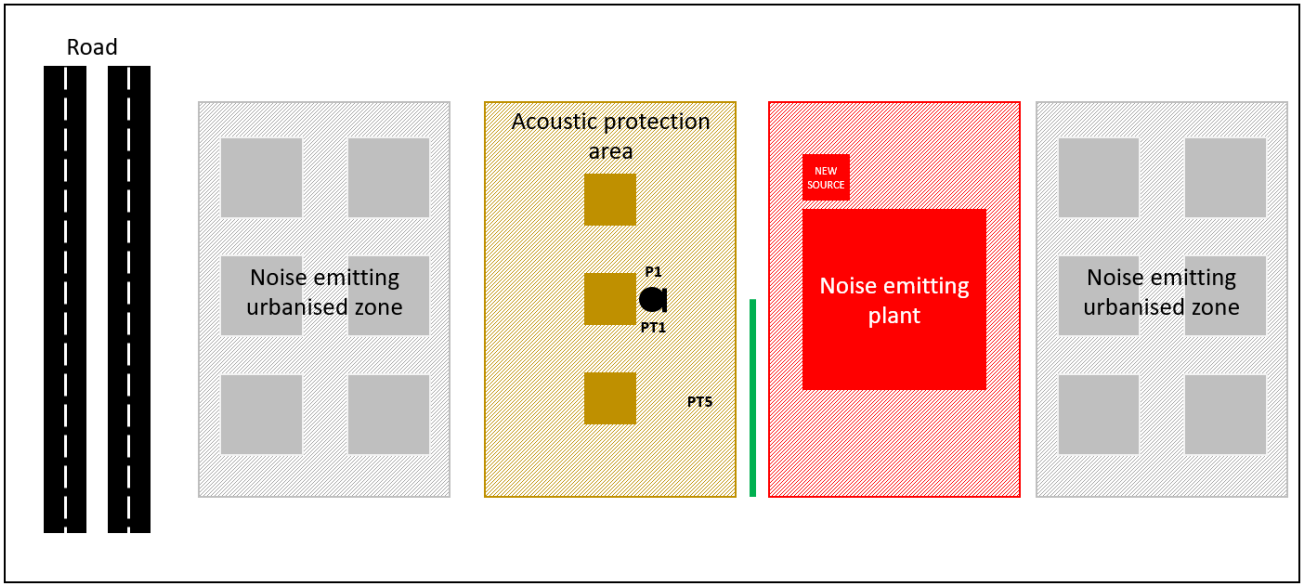
Task:

- Determine the operating modes of the establishment
- Select a place for evaluation
- Selection of measurement locations with an acoustic camera
- Determination of the measurement methodology
- *Inventory of noise sources*
- *Collection of spatial data*
- Perform measurements
- *Development of a full acoustic model*
- Prepare a report *and rankings of sources*

Comments:
Complete measurement to take account of noise levels, exceedances, location and sound power level of sources, building a spatial database. Based on this measurement, actions can be identified.

Environmental acoustics – targers for acoustic analysis

- Selection of equipment with a specified emission level

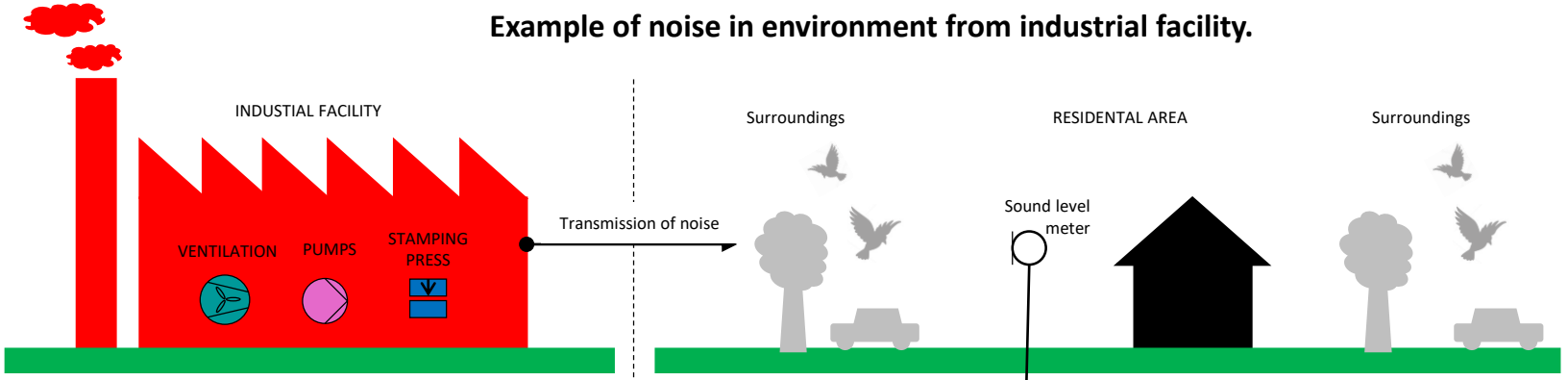


Task:
- Analysis of project documentation
- Analysis of technical data of devices
- Development of an acoustic model
- Testing different variants
- Choosing the optimal solution
- Preparing a report

Comments:
This type of task requires a clear definition of which source to select.
In addition to acoustic issues, economic and technical issues can be taken into account.

Environmental immission, emmission and background noise

Example of noise in environment from industrial facility.



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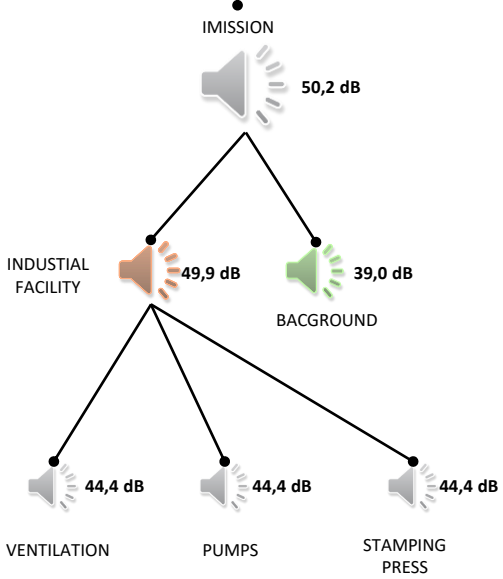
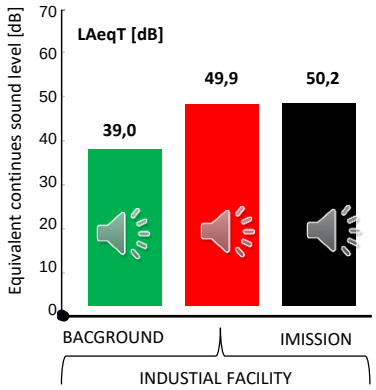
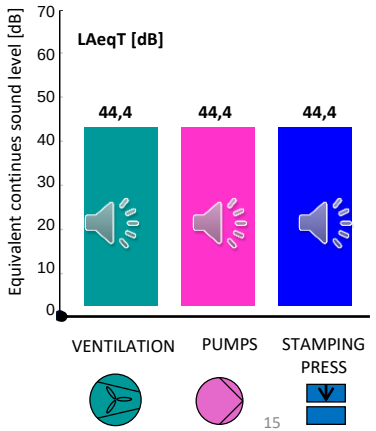






Environmental acoustics – identyfication methods

We can use different paths to identify noise sources.

The selection of the path depends on the complexity of the problem, the possibility of managing the source, the purpose of the analysis.

Four main paths to source identification

ON/OFF

Measurement location:
Checkpoints in the environment

The score:
- Changes noise level at the point,
- Ranking of sources (only if we can on/off every source)
- Assessment of whether the source is dominant
- Optional map with assessment of whether the source/area is relevant

Acoustic camera

Measurement location:
Checkpoints:
in the environment (assessment of immission - "what comes from us")
on the plant (assessment of emmission - "what is issued")

The score:
- Photo/acoustic film showing the main location of noise emission at the checkpoint
- In some cases, the possibility to assess the main noise propagation path (e.g. reflection from the façade)
- Map of the main noise emission sites

Modeling

Measurement location:
Checkpoints:
on the plant (measurements of acoustic power at sources)
in the environment (measurements to calibrate the model)

The score:
- Noise level at checkpoints
- Noise map
- Map of inventoried noise sources
- Ranking of sources at checkpoints

Engineering methods

Measurement location:
Checkpoints:
on the plan (measurements of acoustic power at sources)
in the environment (measurements to calibrate the model)
none (calculations based on data and assumptions)

The score:
- Noise level at checkpoints
- Assessment of whether a source is dominant
- Simplified ranking of sources at checkpoints

Environmental acoustics – identyfication methods

RULE 5 x WHY

(as a child asks us)

1. Why is it loud?
   - Because the chimneys are on
2. Why are the chimneys noisy?
   - Because the fans work
3. Why are the fans noisy?
   - Because the shovels spin and blow the air.
4. Why are fan blades noisy?
   - Because by moving the air they generate a sound wave
5. Why is the air flow loud?
   - Because the rapidly flowing air generates the formation of an acoustic wave

After answering these questions, a new question arises:

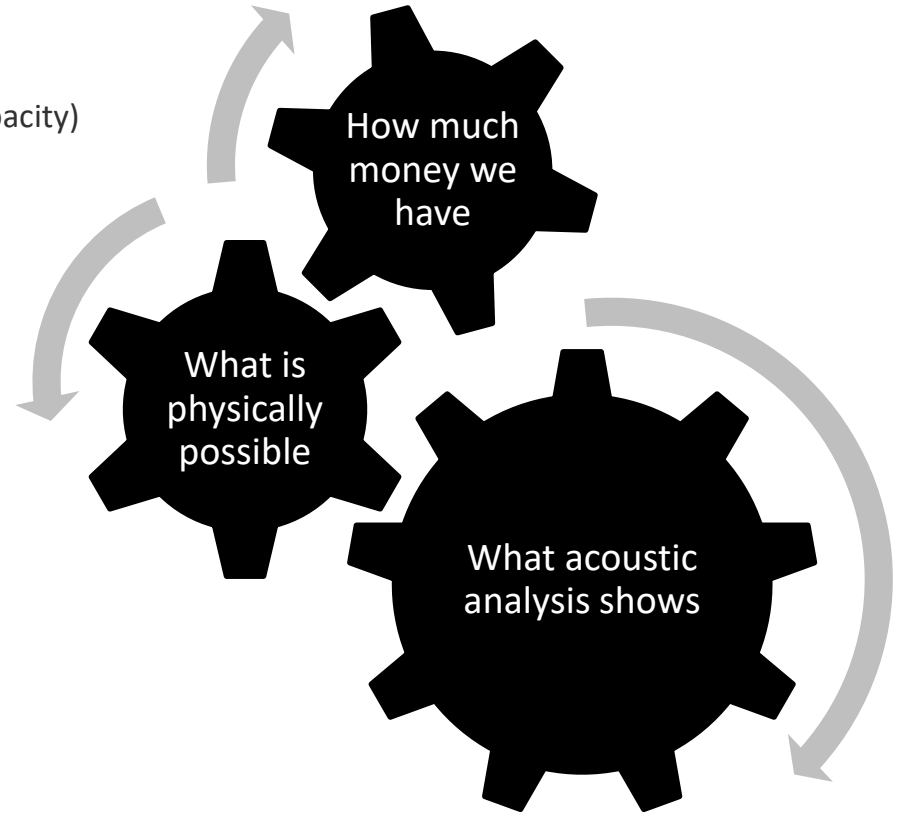
At what point can I start reducing noise?

Most often in point 1 or 2, but the inability to take action directly at the source indicated in points 4 and 5 should be confirmed.

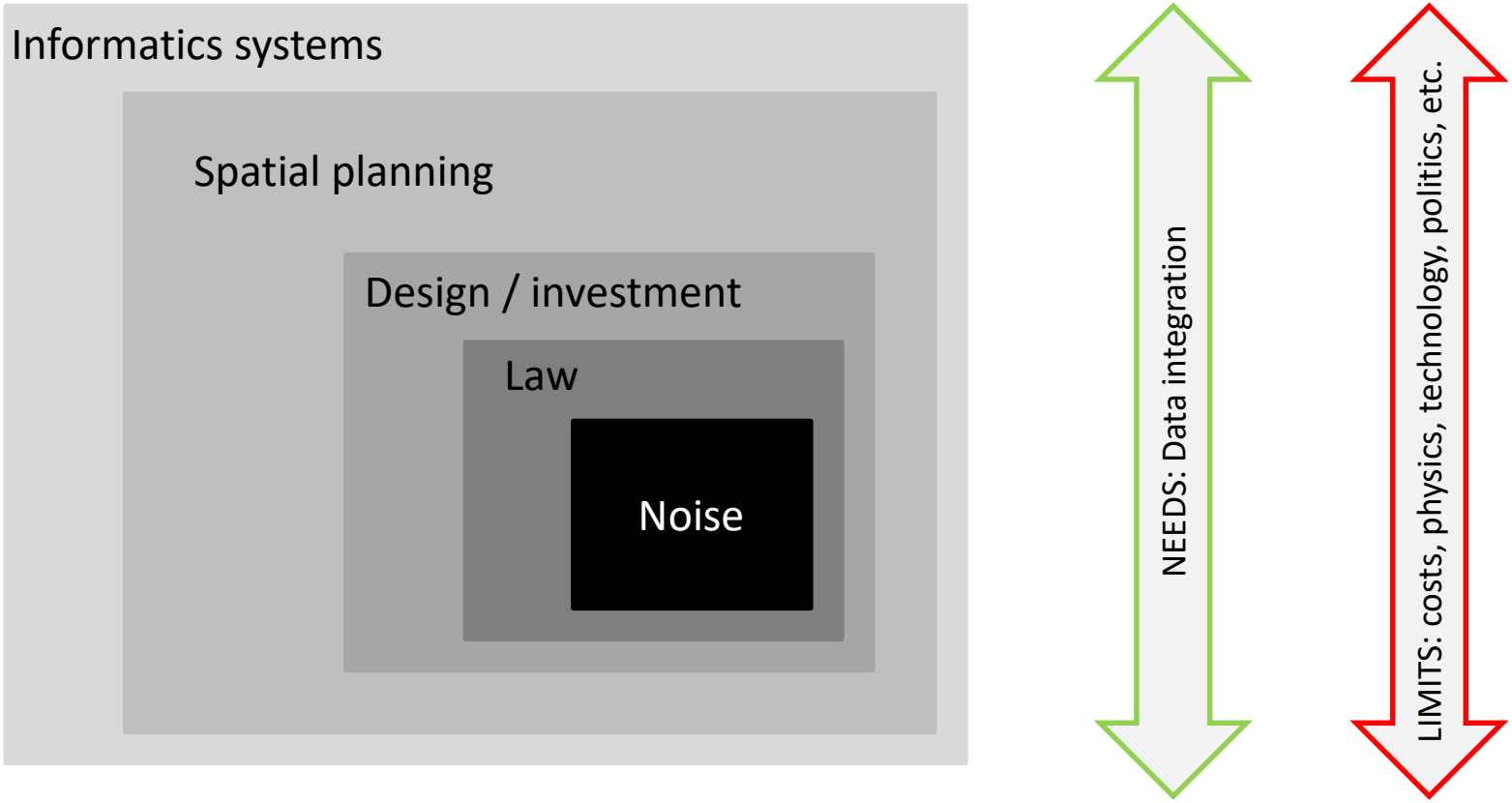
Environmental acoustics – selection solutions

Choosing a solution is a mix

- What acoustic analysis shows
- What is physically possible
- How much money we have
- How there are other restrictions (e.g. roof load capacity)



A broader view - connections with other areas



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Thank you
for your attention

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