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# NONCONVENTIONAL METHOD FOR EVALUATING PARTICULATE MATTER AND/OR COMPOSITES POLLUTION IN CRITICAL AREAS OF RAILWAY TRACK

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ABSTRACT: The railway traffic is an important source of particulate matter and composites pollution. Transport with railways is generally considered as the most environmentally friendly transportation way. Therefore, the high mass concentration of these particulate matter and composites has raised interest among researchers concerning environmental pollution.
Paper presents a nonconventional method for evaluation "in situ" of the state of pollution through statistical analysis of field test results based on experimental optimization methods.
KEY WORDS: Particles, railway, environmental, optimization, method.

## 1. INTRODUCTION

Transport presents real challenges as society tries to ensure a more environmentally sustainable future. Environment is derived from the French word "Environner", which means to encircle or surround.

All the biological and non-biological entities surrounding us are included in environment. As per Environment (Protection) Act, 1986, environment includes all the physical and biological surroundings of an organism along with their interactions. According [1], environment is thus defined as "the sum total of water, air and land and the inter-relationships that exist among them and with the human beings, other living organisms and materials".

This is schematically presented in Figure 1 [1].

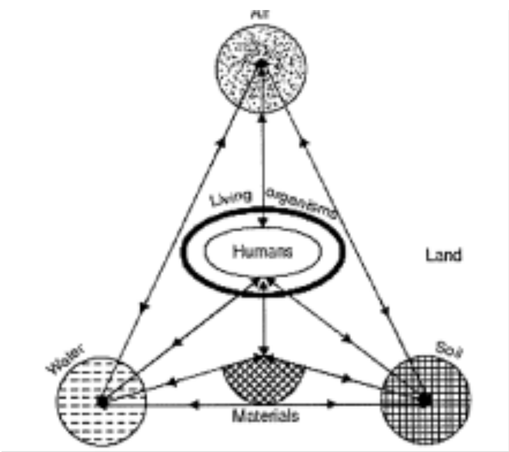


**Figure 1.** Concept of Environment

In terms of environmental quality protection can be considered critical areas also the curves(with different curvature radius) of the railway track because as showing "dynamic forces occurring at elevated wheel-rail contact, producing plastic deformation in the area, discharge of material, crazing and cracking and eventually changes shape tread".

First pollution aspect concern in analyze of noise generated under moving trains, especially high-speed trains [2]

Thus leading to a more pronounced wear of the brake shoes and so at a higher level of pollution with particulate matter and / or composites.

Especially in these areas, the rate of emission from railway rolling stock of particles stemming from wear of brakes and other materials, as well as from re-suspension from the ground, can be expected to depend on train properties such as weight and on driving parameters such as speed and acceleration. Wear of various track components, catenaries, engines, and wagons generally represent a large cost for train operators and railway authorities. Further, wear causes diffusion of valuable material in nature, in the form of polluted water or airborne particles, which may affect ecosystems and human health" [3].

"There are comparatively few studies that address the emission of particles from railways, probably because the impact on air quality is expected to be small. Those that have been completed normally deal with emissions from diesel engines or the air quality in coaches, but with electrical trains, the particles mainly originate from wear of rails, brakes, wheels, and carbon contact strips. The friction between wheels and rail causes metal losses from the surfaces but it is an open question what fraction of these losses results in airborne particles. It is in this context of interest to study particle emissions from railways. A number of studies have reported high concentrations of particles in under-ground stations and subways. There are few studies reporting levels of particles in railway environments above ground and no studies reporting emission factors or the variability in emissions with driving pattern"[3].

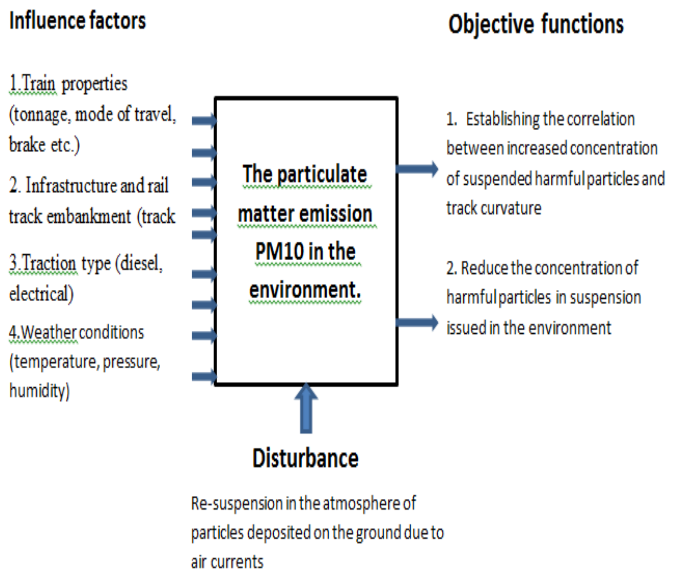


**Figure 2.** Black-box model for the emission of particulate matter

Also, many aspects of extend pollution are available concerning effects on soil, water and organisms biology, included genotoxic effects, and heavy metal enrichment in soils, or both complex effects [4], [5], [6], [7], [8].

Taking into account the above-mentioned, it is proposed to use in my research the following black-box model for the emission of particulate matter.

This paper presents a nonconventional method for evaluation "in situ" of the state of pollution through statistical analysis of field test results based on experimental optimization methods.

## 2 PRINCIPLE OF THE METHOD

In principle, the method is based on the collection of samples from critical areas through a statistically optimized distribution so that number of samples to be minimum and relevance to be maximum.

It will be introduce notion "Pollution function" as global function:

$$Y_p = a_1x_1+a_2x_2+\ldots+a_ix_i\ldots+a_nx_n, \qquad (1)$$

that takes into account several factors of content in few chemical elements like: Fe, Cu, Zn, Ca, Mg, Al, Sb, Na, Ni, Mn, Ba, Cr.

State of pollution modelling involves the following cyclical steps:

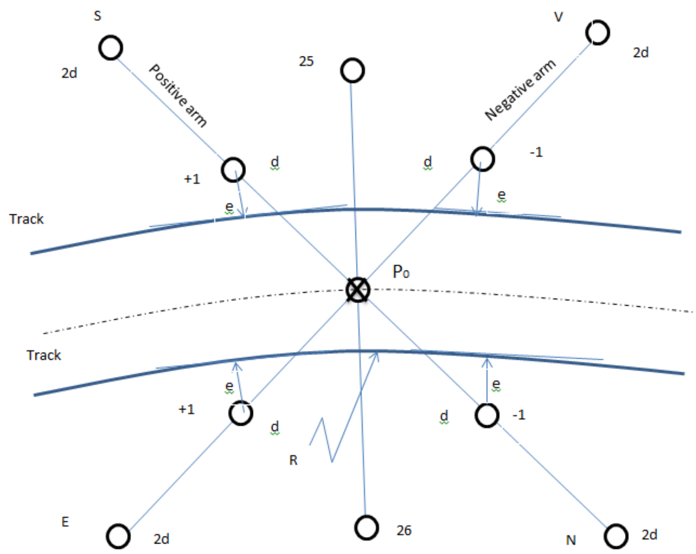


**Figure 3.** Nonconventional proposed method

- adopted initial mathematical modelling structure which established functional links between pollution function and influence factors mentioned above;
- designed of experimental program corresponding to number and variation levels of influence factors;
- direct implementation of the experimentation program associated with a given experimental cycle;
- statistical analysis of experimental results.

For considered method it was proposed to use an experimental strategy, Box-Wilson type, which has the following characteristics [9]:

- progressive acquisition of information after performing experiments;

- achieving a maximum precision of estimating the model for a number of measurement required;
- providing information about the direction of movement of determinations to achieve optimal field of pollution function.

**Table 1.** Program matrix-composite second order of central experiment, orthogonal with $N_0$=2, for k=4, without columns corresponding interactions [9]

| Try. categ. | No.of trial. | Levels of influence factors | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $K_1$ | $K_2$ | $K_3$ | $K_4$ | $K_1^2 \Longrightarrow$ | $K_2^2 \Longrightarrow$ | $K_3^2 \Longrightarrow$ | $K_4^2 \Longrightarrow$ | $Y_{pi}$ |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | 1 | -1 | -1 | -1 | -1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p1}$ |
| | 2 | +1 | -1 | -1 | -1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p2}$ |
| | 3 | -1 | +1 | -1 | -1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p3}$ |
| | 4 | +1 | +1 | -1 | -1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p4}$ |
| | 5 | -1 | -1 | +1 | -1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p5}$ |
| | 6 | +1 | -1 | +1 | -1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p6}$ |
| | 7 | -1 | +1 | +1 | -1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p7}$ |
| $N_L=2^k$ | 8 | +1 | +1 | +1 | -1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p8}$ |
| | 9 | -1 | -1 | -1 | +1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p9}$ |
| | 10 | +1 | -1 | -1 | +1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p10}$ |
| | 11 | -1 | +1 | -1 | +1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p11}$ |
| | 12 | +1 | +1 | -1 | +1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p12}$ |
| | 13 | -1 | -1 | +1 | +1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p13}$ |
| | 14 | +1 | -1 | +1 | +1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p14}$ |
| | 15 | -1 | +1 | +1 | +1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p15}$ |
| | 16 | +1 | +1 | +1 | +1 | 0,215 | 0,215 | 0,215 | 0,215 | $Y_{p16}$ |
| | 17 | -1,483 | 0 | 0 | 0 | 1,415 | -0,785 | -0,785 | -0,785 | $Y_{p17}$ |
| | 18 | 1,483 | 0 | 0 | 0 | 1,415 | -0,785 | -0,785 | -0,785 | $Y_{p18}$ |
| | 19 | 0 | -1,483 | 0 | 0 | -0,785 | 1,415 | -0,785 | -0,785 | $Y_{p19}$ |
| $N_\alpha=2k$ | 20 | 0 | 1,483 | 0 | 0 | -0,785 | 1,415 | -0,785 | -0,785 | $Y_{p20}$ |
| | 21 | 0 | 0 | -1,483 | 0 | -0,785 | -0,785 | 1,415 | -0,785 | $Y_{p21}$ |
| | 22 | 0 | 0 | 1,483 | 0 | -0,785 | -0,785 | 1,415 | -0,785 | $Y_{p22}$ |
| | 23 | 0 | 0 | 0 | -1,483 | -0,785 | -0,785 | -0,785 | 1,415 | $Y_{p23}$ |
| | 24 | 0 | 0 | 0 | 1,483 | -0,785 | -0,785 | -0,785 | 1,415 | $Y_{p24}$ |
| $N_0$ | 25 | 0 | 0 | 0 | 0 | -0,785 | -0,785 | -0,785 | -0,785 | $Y_{p25}$ |
| | 26 | 0 | 0 | 0 | 0 | -0,785 | -0,785 | -0,785 | -0,785 | $Y_{p26}$ |

Number and structure of experimental determinations is given by the next equation:

$$N=N_L+N_\alpha+N0 \quad (2)$$

and the value of distance(from the centre of the experiment $P_0$)where additional points are located is α.

Additional points are at distances "d" and "2d" from the $P_0$.

$N_0$ – number of additional measurements made in the center of the experimental program;

$N_\alpha$ –number of additional measurements made at distance α of the experimental program,

$N_\alpha$ =2k;

$N_L$- number of measurements derived from linear modelling (through complete first order experiment), $N_L$=2;

k-number of influence factors.

In short, nonconventional method proposed by the authors of this work consists of the following:

- It is considered some coupon of railway track whose radius of curvature is R[m] and $P_0$-central point of the experiment situated on the midway of distance between railway tracks.

- For the particular case of pollution function $Y_p$, it was considered 4(four) experimental points positioned at a distance "d" from $P_0$ and "e" to the tangent of the railway track curvature.
- Also it was considered another 4(four) extra points situated away "2d" from $P_0$ on the same 2(two) perpendicular axes with directions N-S, E-W.
- Measurements for "i" factor were used to determine $E_{di}$=f(d), where $E_{di}$ represent pollution effect due to "i" factor.

The factors of influence are [10]:

- $K_1$-distance to the railway tracks(positive or negative arms);
- $K_2$-railway curvatures (minimum and maximum radius);
- $K_3$-seasons (summer/winter);
- $K_4$-directions (East-West and North-South)

We proposed the experiment: $2^k=2^4$ using data from Table 1 [9].

## 3 CONCLUSIONS

The evaluation of particulate matter and/or composites pollution in critical areas of railway track is a complex and laborious process, that involves different methods, experiences and expanse many resources.

Practical applications determine the use of special methods with the optimisation as most important objective.

Such modern methods involve, in the same time, both use of nonconventional elements and, also, the use of modern application of statistical methods.

One important part is the application of the collection of samples from critical areas through a statistically optimized distribution so that number of samples to be minimum and relevance to be maximum.

In such situation it is important to use the "Pollution function" as global function, depending on many linked factors.

## 4 ACKNOWLEDGEMENT

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## 5 REFERENCES

1. C.P. Kaushik, S.S. Bhavikatti, A. Kaushik Basic civil and environmental engineering, *Daryaganj, Delhi, IND:New Age International*, 2010, pp.73.
2. Zhang Xun, Li XiaoZhen, Liu QuanMin, et al - Theoretical and experimental investigation on bridge-borne noise under moving high-speed train, Science China-Technological Sciences, Vol.56, Issue: 4, Pages: 917-924, (2013)
3. E.Fridell, A.Bjork, M.Ferm, A.Ekberg, "On-board measurements of particulate matter emissions from a passenger train", Proc. IMechE Vol.224 Part F, *J. Rail and Rapid Transit*.
4. Sutton, Nora B., Maphosa Farai, Morillo Jose A., et al. - Impact of Long-Term Diesel Contamination on Soil Microbial Community Structure, Applied and Environmental Microbiology, Vol. 79, Issue: 2, Pp. 619-630 (2013)
5. Jung Mi Hyun, Kim Ha Ryong, Park Yong Joo, et al. - Genotoxic effects and oxidative stress induced by organic extracts of particulate matter (PM10) collected from a subway tunnel in Seoul, Korea, Mutation Research-Genetic Toxicology and Environmental Mutagenesis, Vol.: 749, Issue: 1-2, Pp: 39-47 (2012)
6. Zhang Hua, Wang Zhaofeng, Zhang Yili, et al. - The effects of the Qinghai-Tibet railway on heavy metals enrichment in soils , Science of the Total Environment, Vol.: 439, Pages: 240-248 (2012)
7. Gustafsson M., Blomqvist G., Swietlicki E., et al. - Inhalable railroad particles at ground level and subterranean stations - Physical and chemical properties and relation to train traffic, Transportation Research Part D - Transport and Environment, Vol. 17, Issue 3, Pp: 277-285, (2012)
8. E.Fridell, M.Ferm, A.Ekberg, "Emissions of particulate matters from railways – Emission factors and condition monitoring," *J. Transportation research part D* 15(2010) 240-245.
9. E.F. Cicala, *"Statistical processing methods of experimental data"*, Editura Politehnica (1999)
10. L.I. Dungan, " General concepts regarding safety against derailment", Buletinul AGIR nr.1-2/ 2009 pag.117-122.