Estimation of informal transport motorcycle emissions in the city of Ocaña, Colombia, as research training strategy for environmental engineering students

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Abstract. Mototaxism in Colombia is considered an informal employment, in which a motorcycle is used to provide public service; it is a door-to-door service, without established routes, at a perennial frequency and low fares. This modality of employment began in the city of Ocaña about a decade ago, now it has popularized due to population growth, regional migration crisis and high unemployment rates. The “Universidad Francisco de Paula Santander” and the “Universidad Manuela Beltran” in Ocaña, Colombia; from their missional framework, aim to incentivize research training, raising the need to build training projects for students of second and third semester of environmental engineering, integrating statistics as a tool for decision making and data analyses, bringing the academy closer to contextual problems that the students can understand as their own. Environmental engineering students were able to participate with presentation of their results in different events, incentivizing their interest towards research and the use of statistics and mathematics as an important tool for data management and interpretation.

1. Introduction
Mototaxism, as a service, has been implemented in our country as an informal conveyance modality, emerging as an informal way to fulfill the need for employment for people with limited resources [1]. This has caused a significant increase in the use of motorcycles, thus increasing air pollution in forms of emissions such as carbon monoxide, photochemical oxidants, sulfur and nitrogen oxides, and particulate material; products of combustion. On the other hand, authorities are lacking control and awareness communication to the public, leading to a significant raise in traffic accident rates, making mototaxism a focal point for environmental, social, and public health issues for users, providers and bystanders alike [2,3]. Therefore, mototaxism has positioned as an informal employment and alternative economic source for hundreds of Colombian families, however, intensifying problems that drawback innovation and competitiveness in regional development [4].

The city of Ocaña, Colombia is no stranger to this phenomenon, since conveyance constitutes a fundamental element within the spatial structure of the city; competitiveness, productivity and environmental sustainability has an important repercussion in city development, for that reason, continuous and persistent planning is demanding for a growing city [5]. Additionally, legislation regarding the emission of pollutants in mobile sources in Colombia is very recent and even more so for motorcycles, which together with the ignorance of the owners about the minimum maintenance
conditions recommended by the manufacturers and reckless operation, incur in a large emission of combustion gases that is intensified for two-stroke motorcycles [6].

From an environmental perspective, motorcycle is considered a mobile source of emission, generating polluting gases that are released into the atmosphere; for the determination of these, dynamic measurements are used, such as the calculation with emission factors, since currently there is no available equipment for this application. Emission of these volatile compounds into the atmosphere has become a threat to public health; these anthropogenic discharges cause changes in the chemical nature of the environment, the interaction between the compounds generated by combustion and meteorology generates more damaging pollutants, such as tropospheric ozone, making this problem even more difficult to eliminate or mitigate [7].

With this problem in mind, universities in Colombia turn to formative research with the intention of giving contextual problems for students to solve and be involved in, resulting in a potential solution and significant learning experiences. Formative research is the use of research to train in research, to learn to research with its practice, so the students develop interest in various social, scientific and environmental situations, as early as possible with a learning strategy emphasizing learning by discovery and construction; making the students prone to the autonomous search for knowledge [8-10].

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2. Methodology

Within the teaching-learning processes in the subjects of environmental sociology and environmental chemistry, a project-based learning strategy was worked on, with emphasis on significant experience learning; where the student develops a research project within the semester, expanding their abilities from a learning by doing methodology. One of such projects was developed on the estimation of the emissions of motorcycles of informal transport in the city of Ocaña, Colombia; it was carried out within the quantitative paradigm, as a descriptive investigation. Starting from a population count of the motorcycles dedicated to informal transport and an identification of the engine characteristics, in order to find, through a statistical process, an estimate of the emissions produced by this conveyance modality.

In order to promote research training in environmental engineering students, classroom projects were developed in the subjects of environmental sociology and environmental chemistry. In the first one, a diagnosis of social problems, inherent to mototaxis, was made; while in the second, environmental problems were evaluated by calculating vehicular emissions. A survey was carried out to collect model information, type of engine, displacement, working hours and age of the motorcycles that would be used in the selection of the emission factors. A preliminary diagnosis was made to take the collection points of greater influx of the motorcycle drivers in the center of the city of Ocaña, Colombia; finding a greater concentration of these around four specific coordinates, described in Figure 1.

In order to estimate the mass of pollutants emitted in motorcycle activity, a series of calculations were carried out. It was necessary to estimate a daily traveling distance per vehicle; this was achieved employing an average working time in hours per day and average speed in km/h, based on the current speed limit for urban areas established in the “Código Nacional de Transito”, Article 106.

There is a wide selection of emission factors for mobile sources, each one specific to engine characteristics, in this study, we took into consideration motor displacement, vehicle mileage, whether if it was a two-stroke or a four-stroke engine, and according to the work of Herrera [11] in Bogotá, Colombia, emission factors were assigned to each motorcycle class. Finally, pollutant mass was calculated according to Equation (1).

\[ E = t \times \bar{V} \times F \]  
(1)
Where $E$ is pollutant emission; $t$ is working time, obtained from the surveys; $V$ is average speed, established with the speed limit for urban areas within the National Transit Code; and $F$ is the emission factor, which is different for each pollutant, vehicle category and engine characteristic.

Data was processed for all sampling points, calculating emission density within the urban area of Ocaña city according to Equation (2):

$$\rho_E = \frac{E}{S}$$

(2)

Where $\rho_E$ is emission density (pollutant emitted per surface unit); $E$ is pollutant emission, calculated from Equation (1); and $S$ is the surface of the city’s urban area, retrieved from mayoralty data [12].

3. Results

All collected data was processed and analyzed comprehensibly. It was found that the vast majority of motorcycles employed for public service in Ocaña had engines under 250 cc displacement. As it can be seen in Figure 2, the most popular model is the Suzuki GN-125, while the least common models are of the Honda brand.

Pollutant emissions were estimated following Equation (1) with data collected from four sampling points (SP 1-4) to select the appropriate emission factors; results were averaged to a daily rate. Figure 3 shows that Carbon monoxide (CO) emissions average to 3569 kg, while volatile organic compounds (VOC) emissions are close to 860 kg, nitrogen oxides (NOx) emissions reached an average of 129 kg, and 12.9 kg of particulate material with average size of 2.5 µm (PM 2.5). This means that 4571 kg of pollutant agents are being emitted every day.

Comparatively, a highly dense city such as Bogotá, is estimated to have an emission rate 64100 kg/day due to motorcycle activity; however, when comparing emission density, calculated with Equation (2), it is found that for its size, Ocaña’s emissions exceeded those of Bogotá. In Ocaña, motorcycle total emissions density was estimated to 656769 kg/day km², while Bogota’s motorcycle emission density was 168808 kg/day km², nearly 4 times smaller. This leads to conclude that for its size,
Ocaña has a very dense emission pattern, indicating high contamination as consequence of the extensive use of motorcycles for public transport.

![Motorcycle model proportion.](image)

**Figure 2.** Motorcycle model proportion.

![Estimated pollutant emissions per sampling point and averaged.](image)

**Figure 3.** Estimated pollutant emissions per sampling point and averaged.

4. Discussion

Classroom projects linked to the research training should be integrated in knowledge development, constituting a fundamental complement in the learning process for personal, academic and professional formation [12]; thus, universities become an instrument towards the application of the acquired and constructed knowledge from the classroom to other areas. Knowledge based on research, contextualization, interdisciplinary, flexibility and participation, may help the students to achieving a global conception of current problems and possible solutions, arising through experimentation. The problem of mototaxism in the city center of Ocaña, Colombia, is an important study case example for the application of research training; the social problems that impacts a community full of conflicts, the
scarcity of formal employment, and hindered access to education, among others. During the development of this projects, students of environmental engineering of the second and third semester recognized the importance of diagnosing problems; they inquired about the causes of the use of informal transport, but also its impact over the environment through the use of statistical tools, information gathering and works previously done in other cities of Colombia.

5. Conclusion
Environmental engineering students were able to participate with presentation of their results in different events, incentivizing their interest towards research and the use of statistics and mathematics as an important tool for data management and interpretation. It was established that the public transport situation of Ocaña city has the potential to become a serious pollution problem for urban and rural areas alike. The students recognized the importance of diagnosing a problem and show the intention to continue working on this kind of environmental problems along their professional formation.

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