SMART TRANSPORTATION - FROM AIR POLLUTION TO INDIVIDUAL VEHICLE REDUCING

Nguyen Vo Chau Ngan

College of Environment and Natural Resources - Can Tho University

1. INTRODUCTION

The process of urbanization is progressing rapidly in Vietnam, contributing to economic and social development, and improving the quality of life for the people. The urbanization rate in Vietnam leads the Southeast Asia region, reaching 30.5% in 2010 and increasing to 42.6% in 2023 (Trần Thị Lan Anh, 2022). The opportunities and amenities in major cities attract a large number of residents from rural areas and smaller cities, increasing population density and thus escalating demands for essential needs such as housing, employment, and transportation. Consequently, activities of motorized vehicles, production facilities, residents' daily activities, waste management, and pollutants from suburban areas put significant pressure on the environment in urban areas.

The Vietnam Environmental Status Report noted that air pollution is one of the pressing environmental issues for the period 2016 - 2020 (MoNRE, 2021), particularly arising from road traffic activities. The growth of motorcycles in our country averaged 9.1% per year during 2005 - 2022, with about 69.2 million registered motorcycles and approximately 45.5 million in circulation (Phan Hoàng Phương, 2023). Statistics for 2022 show that motorcycles account for 91% of vehicles in Ho Chi Minh City, 90% in Da Nang City, and 84% in Hanoi out of the total number of transport vehicles (Phạm Giang & Tường Vũ, 2023). Air pollution is primarily due to dust (TSP, PM10, PM2.5, etc.), which mainly affects the elderly, pregnant women, children, and people with weak immune systems. Dust and emissions impact various parts of the human body, causing numerous diseases, particularly respiratory diseases, putting significant pressure on the healthcare system, the economy, and social issues. WHO (2024) reported that around 60,000 deaths annually are related to air pollution in Vietnam.

Cần Thơ City, the largest urban area in the Mekong Delta with 9 districts and a total population of approximately 1.44 million people, has nearly 44% of its population residing in the central districts of Ninh Kiều, Bình Thủy, and Cái Răng. These are also the districts with the highest population density in the city, especially Ninh Kiều District, which has a density of up to 10,203 people/km^2, 31.8 times higher than the lowest density in Vĩnh Thạnh District, which is 321 people/km^2 (Table 1). With the dense population, the number of personal vehicles continuously increases over time, leading to more frequent and severe traffic congestion. Ninh Kiều District has 5 hotspots frequently congested during peak hours, including the intersections of Mậu Thân - 3/2 - Trần Hưng Đạo, Mậu Thân - Nguyễn

Văn Cừ - Võ Văn Kiệt, Nguyễn Văn Linh - Nguyễn Văn Cừ, Nguyễn Văn Linh - 3/2, and Nguyễn Văn Linh - 30/4. Traffic congestion leads to slow-moving vehicles, increasing the amount of dust and emissions, causing air pollution. Hồ Quốc Bằng (2018) noted that motorcycles contribute 37.7% of dust, 90% of CO, 65.4% of NMVOC, and 29% of Nox, leading the list of transport vehicles.

Table 1. Area, population, and population density in 2023 for central districts

District	Area (km^2)	Population (person)	Density (person/km^2)
Ninh Kiều	28.90	294,874	10,203
Bình Thủy	70.87	150,528	2,124
Cái Răng	67.82	108,071	1,594
Cần Thơ City	**1,440.40**	**1,258,876**	**874**

(*Source: Cần Thơ City Statistics Office, 2024*)

In 2019, Cần Thơ City approved a clean air action plan until 2025, prioritizing air quality monitoring and reducing major emission sources, especially from transportation and industry (Cần Thơ City People's Committee, 2019). Thanks to this, Cần Thơ became the first city in Vietnam to join the BreatheLife network - a network of cities, regions, and countries committed to achieving safe air quality and cooperating to implement solutions to meet this goal by 2030 (WHO, 2019). This study aims to mitigate air pollution in urban areas, improving the living environment for the community.

The specific objectives of the study include:

- Measuring dust and gas emissions from some types of motorcycles, calculating, and assessing the level of air pollution caused by these vehicles.
- Interviewing 100 residents who use motorcycles about their experiences, awareness of the environmental impact of personal vehicles, and their acceptance of public transportation and green vehicles.
- Proposing solutions to reduce motorcycle usage, aiming towards public transportation or other green transportation modes.

2. RESEARCH METHODS

2.1 Research objective

This research targets two subjects: (i) motorcycles of 10 popular models, (ii) residents using motorcycles in Cần Thơ City.

Interviews and motorcycle emission measurements were conducted on Sep 5 - 25th 2024.

2.2 Data Collection

2.2.1 Secondary data

The research team searched for information and data related to the topic from online

databases, libraries, reports, and scientific papers. The information collected includes the number of motorcycles in circulation in Cần Thơ City, the amount of dust and gas emissions from motorcycles, factors affecting dust and gas emission concentrations, and urban air pollution scenarios caused by motorcycles.

2.2.2 Primary data

a) Interviewing procedure

Interviews with residents in Cần Thơ City about their motorcycle usage experiences, concerns about environmental pollution caused by motorcycles, and their willingness to switch to public transportation or personal electric vehicles.

The interview process includes the following steps:

- Drafting the questionnaire.
- Pilot interviewing 5 people, adjusting the questionnaire.
- Conducting 100 official interviews.
- Inputting and analyzing the collected data.

b) Measuring motorcycle emissions

The emission measurement aims to assess the pollution levels of individual exhaust components from each motorcycle. This allows for estimating the overall air pollution levels in urban areas when motorcycles are in operation simultaneously.

Motorcycles were randomly selected from students and lecturers of Can Thơ University. A total of 35 motorcycles were measured, each measured 3 times to obtain average results. The research team designed and manufactured a device to collect exhaust emissions from motorcycles (Figure 1). After collecting the emissions into bags, quick measuring devices (Figure 2) were used to measure component gases including CO, N_2O, volatile organic compounds TVOC, Formaldehyde HCHO, PM10 and PM2.5 dust particles (Table 2).

Table 2. Technical specifications of emission measurement devices

No.	Parameter	Unit	Measurement threshold	Equipment, brand-name
1	CO	ppm	0 - 1000 (± 10 ppm)	ExTech CO10 FLIR Systems Inc. (USA)
2	N_2O	ppm	0 - 1000 (± 5 ppm)	GeoTech G200 QED Environmental Systems Ltd. (UK)
3	TVOC	mg/m^3	0 - 9,99 (± 5%)	PCE-RCM 11 Professional Control Equipment Instruments (Germany)
4	HCHO	mg/m^3	0 - 5 (± 5%)	
5	PM10	$\mu g/m^3$	0 - 2000	
6	PM2.5	$\mu g/m^3$	0 - 2000	

Figure 1. Motorcycle emission collection tool for measurement

ExTech CO10 GeoTech G200 PCE-RCM 11

Figure 2. Emission measurement devices used in the study

2.3 Data processing

The data collected from the interview questionnaires sheet and motorcycle emission measurements are entered into Excel spreadsheets for management.

Steps for processing interview data include:

- Data evaluation: Ensuring data is collected correctly, objectively, and according to the initial design.
- Data editing: Checking completeness, consistency, and clarity of data, ready for coding and processing.
- Data coding: Edited responses are identified and classified by numbers or symbols.
- Data analysis: Using statistical analysis methods to draw conclusions on the research content.

For motorcycle emission measurement data, the processing steps include:

- Filtering recorded data according to groups of surveyed motorcycles: Brand (Vision, Wave, Exciter, etc.), type of motorcycle (manual, scooter, clutch), cylinder capacity (< 50 cm^3, 50 - < 150 cm^3, ≥ 150 cm^3), years of operation (< 5 years, 5 to 10 years, 10 - 20 years, > 20 years).
- Calculating the average emissions from each group of surveyed motorcycles.
- Establishing a model to calculate emission levels corresponding to the number of motorcycles operating in the central area of Cần Thơ City.

3. RESULTS AND DISCUSSION

3.1 Interview results

A total of 102 questionnaires were collected, all of which met the requirements after review and evaluation. However, the research team randomly selected 100 questionnaires for data entry and processing, sufficient for the proposed number of interview questionnaires.

3.1.1 General information

Among the 100 respondents, 42% were female, which is not significantly different from the national gender ratio of 51/49 (GSO, 2023). The age of respondents was highest in the 20 - 30 age group at 37%, followed by the 40 - 50 age group at 27%, the 30 - 40 age group at 26%, under 20 years and from 50 to 60 years respectively at 5% and 4%, with 1% of respondents over 60 years old. The professions of respondents were diverse, with 21% being engineers, 18% state officials, 17% teachers, 14% students, 11% service business, 3% in the armed forces, 1% workers, and 15% in other occupations (Fig. 3). With such varied ages and professions, the information provided by the respondents is highly reliable to represent the group of motorcycle users.

The number of household members of respondents primarily ranged from 3 to 4 accounting for 72%, followed by 5 to 6 people at 17%. This result confirms that the nuclear family model (two-generation family consisting of parents and children) is increasingly popular in modern society. In these households, the average monthly income of 12 to 24 million VND was the most common at 36%, followed by 6 to 12 million VND and over 24 million

VND at 24% and 22%, respectively. On a per capita basis, respondents have an average income of 6,000,000 VND/month, comparable to the 6,733,900 VND/person/month of Cần Thơ residents (GSO, 2023). However, 14% and 4% of respondents reported an average monthly income of 3 - 6 million VND/household and below 2,000,000 VND/household, consistent with the report on the income inequality between the highest and lowest income groups being 6.1 times in Cần Thơ City (GSO, 2023).

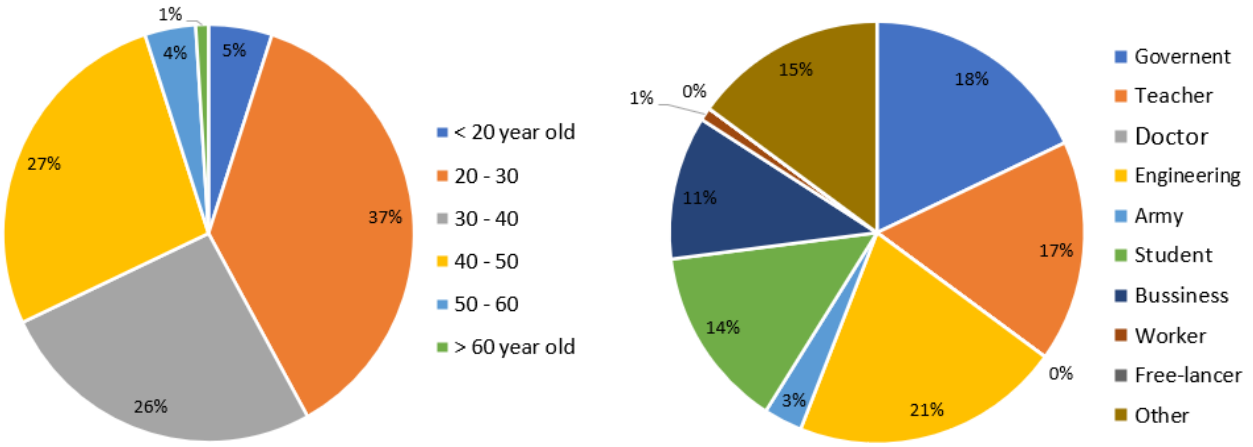


Figure 3. Age and occupation of respondents

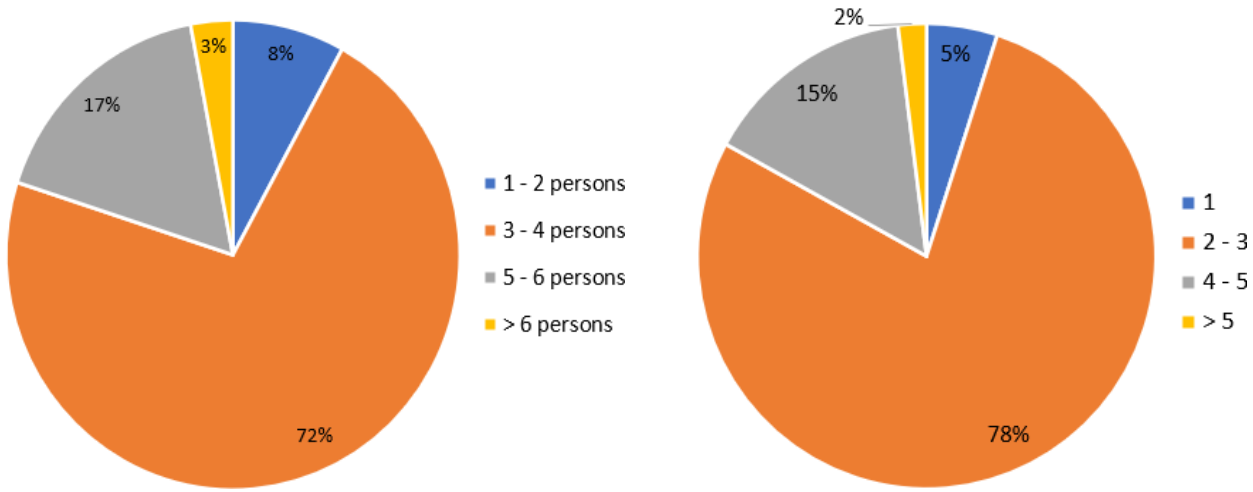


Figure 4. Number of household members and motorcycles per household

The number of motorcycles in respondents' households increased with the number of household members (Fig. 4). Households with 2 - 3 motorcycles accounted for the highest rate at 78%, followed by households with 4 - 5 motorcycles at 15%, 5% of households had only 1 motorcycle, and 2% had more than 5 motorcycles. For a nuclear family with parents and an average of 2 children, the number of motorcycles would be 2, which can increase to 3 when the older child reaches high school and needs independent transportation for studies. Thus, the motorcycle rate per population is 75%, equivalent to the 72.8% rate reported by Seasia Stats in 2023, making Vietnam the country with the highest motorcycle usage in Southeast Asia, followed by Brunei with a rate of 67.2%, Malaysia 45.2%, Indonesia 45.1%, Thailand 30.6%, etc. (Nguyễn Thúc Hoàng Linh, 2024).

Considering the total sales of the Vietnam Association of Motorcycle Manufacturers (VAMM), although motorcycle sales have 'saturated' they still maintain relatively stable levels (Table 3). This statistic only includes the purchasing power of motorcycles from the five major brands Honda, Yamaha, Suzuki, Piaggio, SYM, indicating that the demand for motorcycles in Vietnam remains very high.

Table 3. VAMM sales from 2020 to 2024

No.	Fiscal year	Sales revenue (unit)	Note
1	2019	3.254.964	Decrease 3,87%
2	2020	2.712.615	Decrease 16,66%
3	2021	2.492.372	Decrease 8,12%
4	2022	3.003.160	Increase 20,49%
5	2023	2.516.212	Decrease 16,21%

(*Source: VAMM 2020, 2021, 2022, 2023, 2024*)

3.1.2 Motorcycle usage and environmental pollution

Regarding the brands of motorcycles currently in use, 80% of respondents reported using Honda motorcycles, 13% Yamaha, 2% SYM, 1% Piaggio, and 4% other brands. In 2023, Honda continued to be the largest motorcycle manufacturer, holding more than 80% of the motorcycle market share in Vietnam (Nguyễn Thúc Hoàng Linh, 2024). This statistic completely matches the survey data.

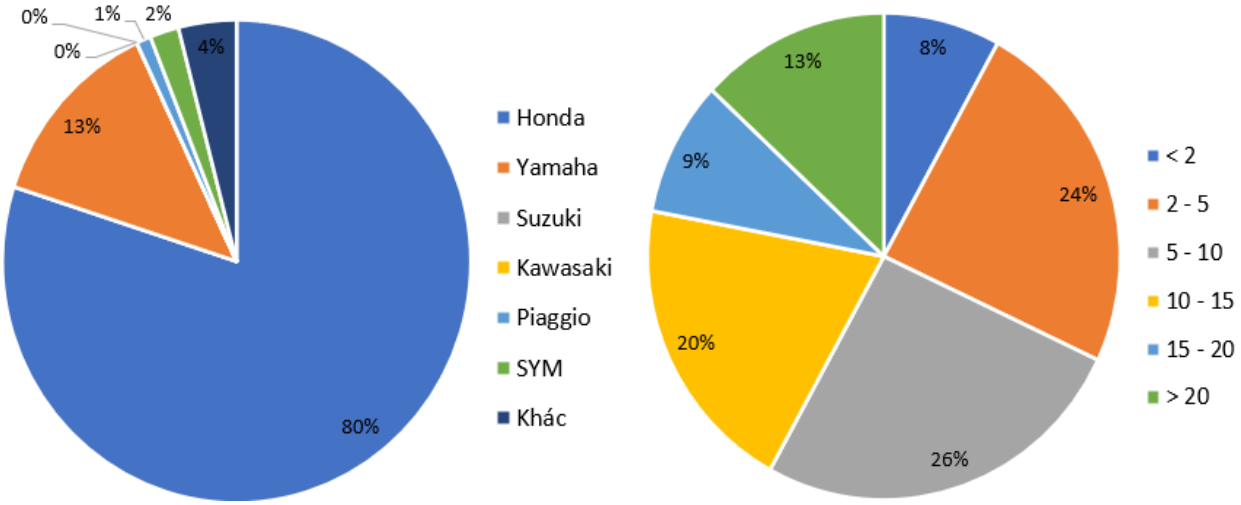


Figure 5. Motorcycle brands and years of usage

The years of motorcycle usage are calculated from the time of purchase to the present. Respondents' usage times varied widely, with 8% using their motorcycles for less than 2 years, 24% for 2 - 5 years, 26% for 5 - 10 years, 20% for 10 - 15 years, 9% for 15 - 20 years, and 13% for more than 20 years. The data on years of motorcycle usage aligns with the respondents' age range of 20 - 50 years. The group with the highest years of motorcycle usage of 2 - 15 years corresponds with the highest age group of 20 - 40 years.

Among the surveyed motorcycles, scooters accounted for the highest rate at 55%, followed by manual motorcycles at 43%, and clutch motorcycles at 2%. Huỳnh Trường Huy and Trần Túy Hỷ (2014) surveyed factors influencing people's choice of scooters. Consumers' needs and decisions to purchase scooters are influenced by brand, price, technical features, design, safety, personal expression, and warranty policies. In contrast, personal characteristics (such as age, education level, occupation, and income) did not influence the need and decision to purchase scooters. Present in Vietnam since the 1990s, the proportion of scooters sold reached 30% by 2010 and increased to 45% in 2015 (Thượng Tâm, 2020). Scooters have become increasingly popular due to their ease of operation, attractive design, and new, modern technology. Currently, scooters hold over 45% of the market share and are expected to experience strong growth in the future (Văn Xuyên, 2024).

The engine displacement of motorcycles used by respondents is predominantly 100 - 175 cm^3, accounting for 71%, 27% motorcycles with a cylinder capacity of 50 - 100 cm^3, and 2% motorcycles under 50 cm^3 (Fig. 6). The cylinder capacity in modern motorcycles tends to be larger, providing more power to meet the dynamic needs of young people. Advances in technology, such as electronic fuel injection, have reduced fuel consumption despite increased cylinder capacity.

Many respondents showed concern about the type of fuel used for motorcycles, with 88% using RON 95 gasoline. However, with 55% of respondents using scooters and 71% using motorcycles with larger displacements, the high percentage using RON 95 gasoline is not appropriate. Most consumers tend to refuel out of habit, choosing gas stations along their route from home to work or school. If the gas station attendant does not receive specific instructions, they typically assume the consumer wants RON 95 gasoline. This could explain the high percentage of respondents using RON 95 gasoline. Additionally, 5% of respondents did not care about the type of fuel used, indicating a lack of concern for their vehicles and environmental pollution caused by motorcycle emissions.

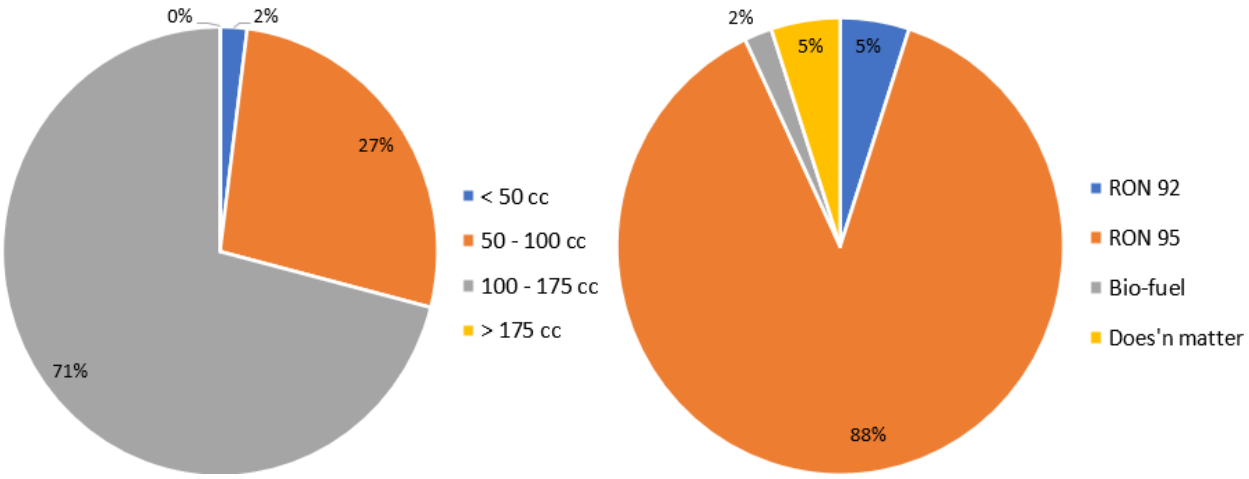


Figure 6. Motorcycle cylinder capacity and fuel type

Due to the high-octane rating of RON 95 gasoline, the fuel supply time to the engine combustion chamber is shorter, meaning less fuel is consumed. RON 95 gasoline is

recommended for high-compression motorcycles (over 10 : 1) such as SH, Air Blade, Piaggio, helping the engine run smoothly with high anti-knock capabilities. Lower compression motorcycles (below 10 : 1) like Future, Wave, Super Dream, Nouvo, Sirius, Jupiter should use RON 92 gasoline. While RON 95 can be used for lower compression motorcycles, it provides no benefit and is not economical. Using the correct gasoline type helps the engine operate efficiently, reduces wear and tear, and saves fuel.

For motorcycles still under warranty (typically the first 2 years), maintenance is tracked and performed by manufacturers through customer service. For motorcycles out of warranty, many customers become engrossed in daily tasks and neglect maintenance. However, 87% of respondents reported maintaining their motorcycles, even though 92% had used their motorcycles for over 2 years, showing concern for their vehicles. 9% reported not maintaining their motorcycles, and 4% were unaware of the need for motorcycle maintenance. The frequency of maintenance also varied among respondents, with 42.5% performing maintenance once a year, 23% twice a year, 18.4% three times a year, and 16.1% four or more times a year.

Regular maintenance is crucial for motorcycle safety. It helps detect and address worn parts such as spark plugs, air filters, oil filters, belts, chains, and brakes. Worn parts can reduce efficiency, increase fuel consumption, cause noise, and damage the engine. Regular motorcycle maintenance is recommended every 1,000 - 5,000 km or every 6 - 12 months, depending on usage and terrain. Frequent use or travel on rough roads requires more frequent maintenance. Regular maintenance extends the lifespan of components and saves repair costs.

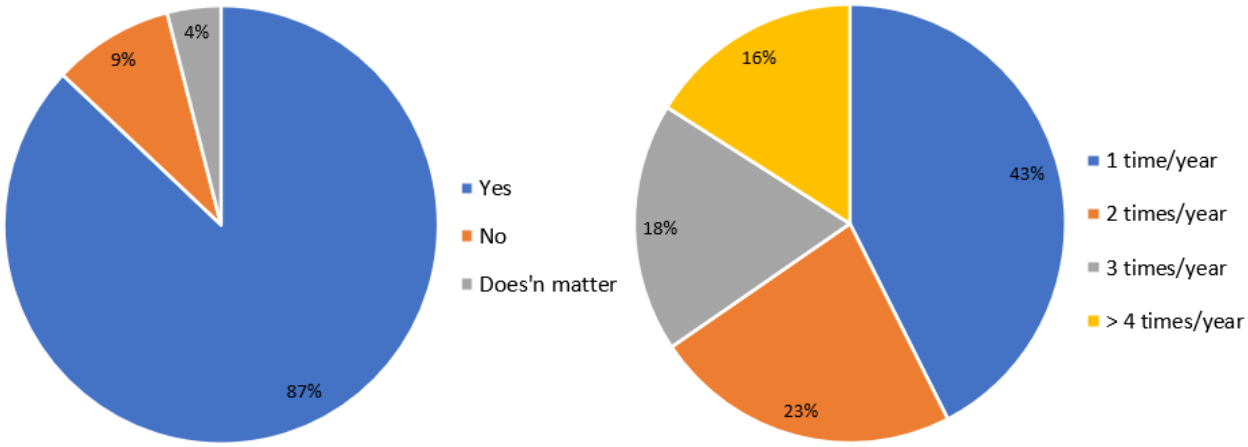


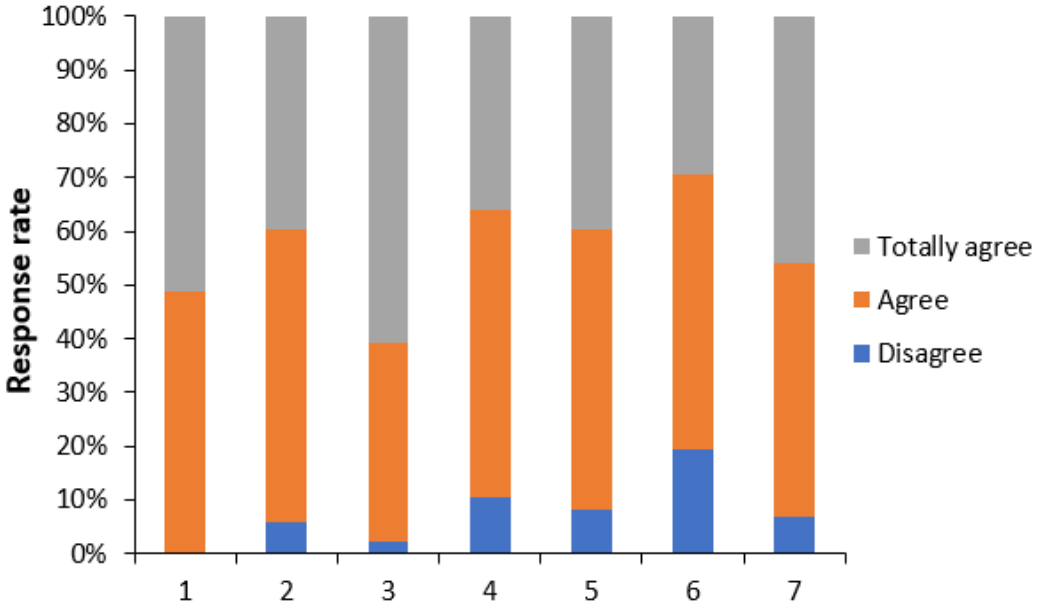
Figure 7. Maintenance habits and frequency

When asked about preferred maintenance locations, 42.5% of respondents chose official service centers (typically where the motorcycle was purchased or authorized dealers). Familiar repair shops accounted for 31%, and convenient locations 13.8%. Many road users in Vietnam lack the habit of periodic vehicle maintenance as recommended by manufacturers. Vehicles after a period of use may have leaky fuel injection systems, posing a fire hazard, and incomplete combustion generating benzene in exhaust, increasing fuel

consumption and harmful emissions. Additionally, high motorcycle density and inadequate road networks contribute to increasing air pollution emissions from motorcycles.

Studies in Vietnam have examined the levels and impacts of dust and emissions from transportation on air pollution. Monitoring results in Ho Chi Minh City found traffic activities accounted for the highest emissions with 99% CO, 97% NMVOC (non-methane volatile organic compounds), 93% NOx, 78% SO_2, 46% dust, and 64% CH_4 (Hồ Quốc Bằng, 2018). In Hanoi, using the IVE and EMISENS models to determine average emissions for motorcycles, Trần Thị Hồng Hiền et al. (2023) recorded total emissions of 5,261 tons of dust, 22,478 tons of NOx, 845,340 tons of CO, and 345 tons of SO_2 per year.

When asked about motorcycles' ability to cause environmental pollution, 87% respondents were aware, 9% did not know, and 4% had not heard about this issue. For those aware of motorcycle pollution, their understanding of the causes of pollution is shown in Fig. 8 with three levels of agreement. Except for reason (1), which all respondents agreed on, other causes had disagreement ranging from 2.3% to 19.5%. Respondents agreeing with the causes of pollution ranged from 36.7% to 54.7%. The cause of too many motorcycles in the city had 60.9% strongly agreeing, while only 29.3% strongly agreed with hearing about motorcycle pollution from media. This shows limited access to information related to transportation pollution. Therefore, diverse information channels should be utilized to better convey this to consumers, including newspapers, radio, television, websites, advertising panels, conferences, and seminars. Especially as the deadline for motorcycle emission testing approaches on Jan 01st 2025 as per the Law on Road Traffic Safety (Vietnam Gazette, 2024), widespread communication is needed to gain public consensus.



Note: 1. Gasoline exhaust contains many emissions *2. Gasoline contains harmful lead*
3. Too many motorcycles in the city *4. Few public transport vehicles (buses)*
5. Many old motorcycles still in use *6. Frequent media reports on pollution*
7. Frequent traffic congestion causing jams

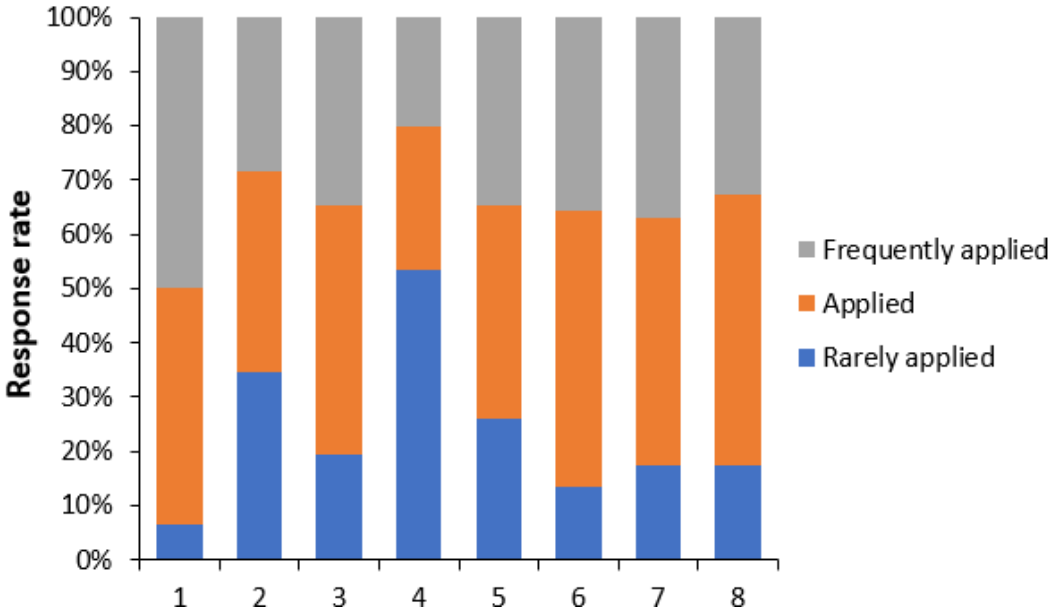
Figure 8. Respondents' understanding of causes of motorcycle pollution

Although 87% of respondents recognize that motorcycles have the potential to pollute the environment, only 51% responded that motorcycles cause pollution and severe pollution to the environment. 38% of respondents indicated that the pollution level of motorcycles is average, 10% did not see any pollution, and 1% noted that motorcycles do not cause any environmental pollution at all.

3.1.3 Reducing environmental pollution from motorcycles

All respondents were asked if they implement solutions to reduce environmental pollution from motorcycles. 46% confirmed they apply these solutions, 38% do not apply them, and 16% are unaware of these solutions. The adoption rate is quite low, accounting for only 52% of respondents who are aware that motorcycles cause environmental pollution. We mention the concept of 'intelligent consumers', but without transparent info and stringent state management, consumers can easily lose direction and cannot make good choices.

Regarding the solutions currently applied to reduce motorcycle pollution, the levels of application chosen by the respondents are shown in Fig. 9. More than 80% of respondents prioritized the solutions of (i) regular vehicle maintenance, (ii) inflating tires properly, (iii) carpooling for work or school, and not using old motorcycles, and (iv) limiting motorcycle use when not necessary. Only 46.67% of respondents chose to use public transportation, indicating that this type of transportation has not attracted much attention from users.



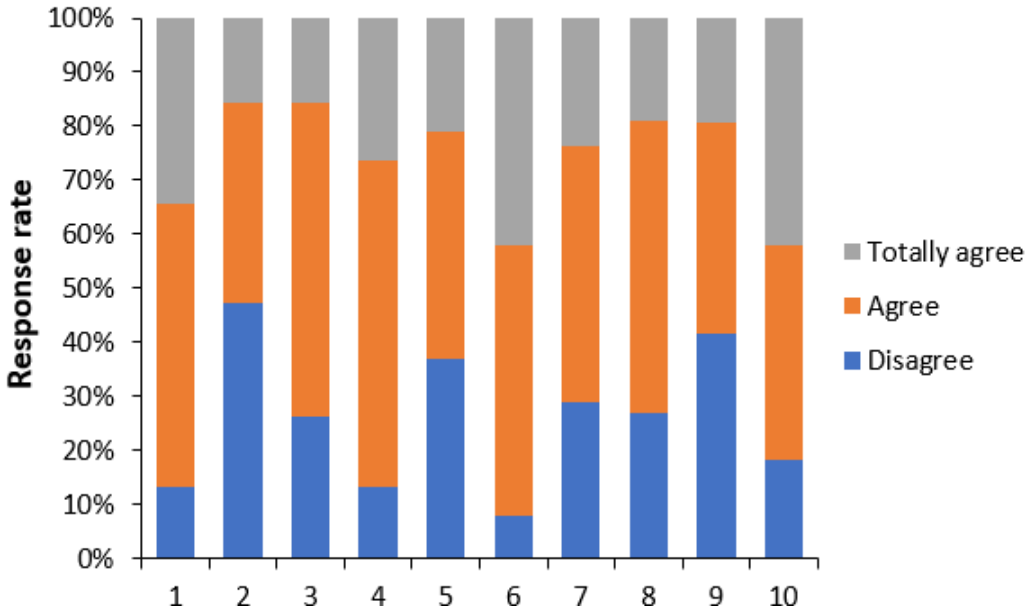
Note: *1. Regularly maintain the vehicle* *2. Use low-lead or biofuel gasoline*
3. Limit motorcycle use when not necessary *4. Prioritize public transportation*
5. Turn off the engine at red lights *6. Inflate tires properly*
7. Carpool for work or school *8. Do not use old motorcycles*

Figure 9. Current solutions to reduce motorcycle pollution

Recently, the Center for Urban Traffic Management and Operations - Department of Transport of Cần Thơ City has been effective in restoring the public transportation system after the Covid-19 period. Currently, within the city, the internal bus routes being operated

include: CT-01 Ba Láng - Ô Môn; CT-02 Cần Thơ International Airport - Phong Điền Town - Ông Hào Victory Monument; CT-03 Ô Môn - Ngã ba Lộ Tẻ; CT-05 Ô Môn - Vĩnh Thạnh; CT-06 Ngã ba Lộ Tẻ (Thốt Nốt) - Kinh B - extended to Kiên Giang Province Bus Station; CT-07 Ngã ba Lộ Tẻ (Thốt Nốt) - Cờ Đỏ Town; CT-10 Phong Điền - Thới Lai; CT-08 Cần Thơ - Giai Xuân - Phong Điền; CT-09 Phong Điền - Lộ tẻ Ba Se - Ô Môn; CT-11 Ba Láng (Cái Răng District) - Trà Nóc Industrial Park - Ô Môn (Trinh T., 2024). However, the bus routes in the city center are not diverse enough in terms of routes and stops, thus not attracting many users.

When asked about the possibility of switching to electric two-wheelers, only 39% of respondents were willing to change; of these, 92.31% were ready to switch immediately. The reasons for switching are presented in Fig. 10 with the highest being environmental consciousness (92.11%), followed by the lightweight and easy maneuverability of electric vehicles in the city and saving money on gasoline (86.84%). Additionally, 81.58% of respondents were concerned that old motorcycles would be recalled after the government implements emission testing. 73.68% respondents said electric motorcycles are convenient for charging, 71.05% found the electric motorcycle brands on the market trustworthy and affordable. However, 36.84% of respondents believed that electric motorcycles need more stylish designs to attract customers.



Note: *1. Save money on gasoline* *2. Less need for maintenance*
3. Easy to charge *4. Lightweight, easy to ride in the city*
5. Stylish design *6. Less environmental pollution*
7. Affordable price *8. Reliable manufacturer*
9. Motorcycles soon require emission testing *10. Old motorcycles will be phased out*

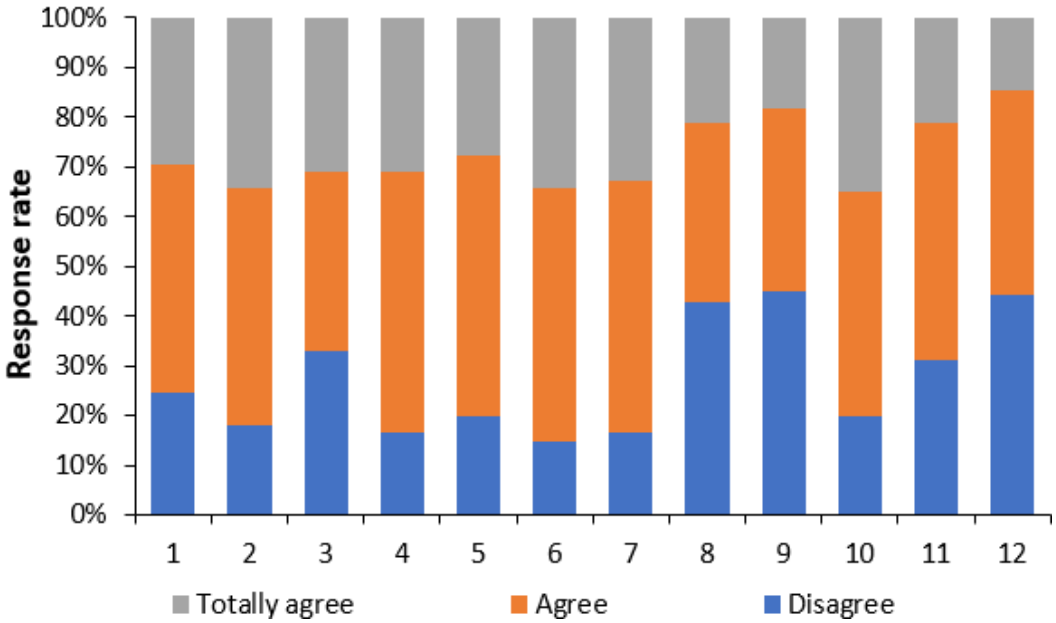
Figure 10. Reasons for switching to electric two-wheelers

Public transportation refers to the types of vehicles that serve the transportation needs of many people at the same time. These vehicles offer convenience, safety, cost savings, and environmental friendliness. In Cần Thơ City, the current public bus system is invested in

and operated by Phương Trang Bus Company, and there is a system of four-wheeled vehicles with 9 to 15 seats running on electric energy (Mỹ Khánh Ecotourism Company, Tân Đại Phong Construction Trade and Production Company) transporting tourists within a limited range in the city (Cần Thơ City People's Committee, 2017). However, when asked if they knew about public transportation, only 65% of respondents said they had information, and only 62% wanted to use public transportation.

Among those who are aware of public transportation, up to 88.89% reported receiving information through social media and internet searches, 82.81% knew through media tools (TV, radio), and 81.54% learned from friends and colleagues. The role of local authorities accounted for only 42.19%, which is quite low in promoting public transportation to the public. This may be because the public transportation system has been privatized and operated by private entities, but attention should be paid to the environmental benefits and safety of this transportation mode.

The reasons people love to use public transportation are presented in Fig. 11. About 85.25% of respondents care about environmental issues, stating that buses cause less pollution; 83.61% agree that using buses reduces traffic congestion and allows them to relax while traveling; 81.97% mentioned that they do not worry about motorcycle maintenance; and 80% feel safer when using buses. However, 45% of respondents noted that the current bus routes are still limited, and 44.26% mentioned that the service attitude of the bus staff is not good.



Note: *1. Saving money on fuel* *2. No doubts on motorcycle maintenance*
3. Buses run on schedule *4. Reducing traffic congestion*
5. Less health impact *6. Less environmental pollution*
7. Helps relax while traveling *8. Opportunity to meet new friends*
9. Many route options *10. Safer transportation*
11. Convenient ticket purchase on the bus *12. Good service attitude*

Figure 11. Reasons for using public transportation

3.2 Measurement and calculation results of motorcycle emissions

3.2.1 Emission calculations

The research team measured emissions from 35 motorcycles of various types (Dream II, Future, Future Neo, Wave Alpha, Wave RSX, Custom, Holder, SH, SH Mode, Air Blade, Vario, Lead, Vision, Blade, Click, BeAt, Sirius, Acruzo, Exciter, MS King…), which can be classified as follows:

- Type of motorcycle: 17 manual motorcycles, 15 scooters, and 3 clutch motorcycles.
- Brand: 27 Honda, 7 Yamaha, and 1 other brand.
- Cylinder capacity: 33 motorcycles with cylinder capacity of 90 to 135 cc, and 2 with a cylinder capacity of 150 cc.
- Years of use: 8 motorcycles used for less than 5 years, 17 for 5 to 10 years, 8 for 10 to 20 years, and 2 for over 20 years. According to Trúc Đào (2024), motorcycles over 5 years old tend to exceed current emission standards, and those over 10 years old have very high emission rates. This study categorizes motorcycles into two groups: under 10 years old and over 10 years old.

The average dust and emissions measured from the groups of motorcycles, classified by type, brand, and years of use, are presented in Table 4. Measurement data show that motorcycles used for over 10 years tend to emit more pollutants than those used for less than 10 years; however, the difference is not statistically significant. When considering motorcycle brands, there is no significant difference in emission levels between Honda and other brands. Only when categorizing by type of motorcycle does a significant difference in emission levels appear between manual and scooter motorcycles.

Table 4. Average dust and emissions from measured motorcycles

Type	**Brand name**	**Used year**	**CO** (ppm)	**N_2O** (g/m^3)	**PM10** (mg/m^3)	**PM2.5** (mg/m^3)	**TVOC** (mg/m^3)	**HCHO** (mg/m^3)
Manual	Honda	< 10 years	1342.83	230.67	1258.83	529.33	7.74	0.01
		> 10 years	1433.29	207.51	845.47	538.68	8.14	0.01
	Other	< 10 years	1569.00	311.00	595.67	269.33	8.72	0.01
		> 10 years	1569.00	302.56	1531.89	1389.78	9.09	0.01
Scooter Clutch	Honda	< 10 years	699.33	144.42	189.71	33.17	5.14	0.05
		> 10 years	1224.28	222.04	631.37	216.74	6.90	0.01
	Other	< 10 years	783.67	124.00	38.33	22.67	5.40	0.01
		> 10 years	1569.00	247.00	185.00	122.33	7.62	0.01

A scenario was selected to calculate emission levels for the entire city and the three central districts as follows:

- The central area of Cần Thơ City has 50% of the motorcycles in operation out of the total 800,000 motorcycles (An Hòa, 2022).
- The number of motorcycles in Cần Thơ City used for over 10 years accounts for 66.5%, the average from three emission measurement programs for motorcycles and motorbikes in Hồ Chí Minh City, Đà Nẵng, and Hà Nội (Trúc Đào, 2024).
- An average motorcycle travel distance of 16.4 km/day was chosen, equivalent to the travel distance of residents in Hanoi (Trần Thị Hồng Hiền và ctv., 2023).
- Based on the survey results from this study, scooters account for 55%. A scenario with a ratio of scooters to other types (manual, clutch) of 1 : 1 was chosen because more measurements were available for manual motorcycles.
- Honda motorcycles account for 80% of the total number selected according to this study's survey results and the market share report of motorcycles in Vietnam (Nguyễn Thúc Hoàng Linh, 2024).

Table 5. Average dust and emissions by motorcycle group and city

Emission / **Types**	**CO** (ppm)	**N_2O** (g/m^3)	**PM10** (mg/m^3)	**PM2.5** (mg/m^3)	**TVOC** (mg/m^3)	**HCHO** (mg/m^3)
Manual	1319.00	214.25	0.947	0.580	7.529	0.009
Scooter	1010.17	181.83	0.380	0.130	5.899	0.020
Center districts	2329.16	396.09	1.327	0.710	13.428	0.029
Cần Thơ City	**4658.33**	**792.17**	**2.654**	**1.420**	**26.856**	**0.059**

3.2.2 The harm of motorcycle emissions to humans

The operation of motorized vehicles causes emissions as follows:

- Movement of the vehicle: all gases.
- Engine operation: CO, NOx, C_6H_6, total organic gases TOG, formaldehyde HCHO, acrolein C_3H_4O, acetaldehyde C_2H_4O, methyl tert-butyl ether $(CH_3)_3COCH_3$.
- Evaporation after the vehicle is turned off: C_6H_6, TOG, $(CH_3)_3COCH_3$.
- Corrosion of body and brakes: various dust particles, including PM10 and PM2.5.

Particulate matter of PM10 and PM2.5 is defined as particles fraction with an aerodynamic diameter smaller than 10 and 2.5 µm. The finer particles can remain in the atmosphere for a longer time even weeks. These finer particles can be transported over longer distances that could change particles' characteristics due to physicochemical processes (Fig. 12).

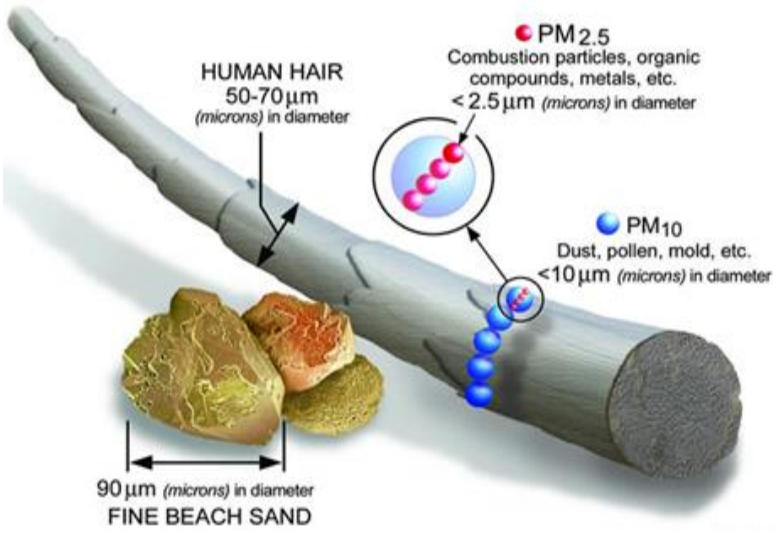


Figure 12. Illustration of dust particle size

(*Source: https://www.irceline.be/en/documentation/faq/what-is-pm10-and-pm2.5*)

Many studies worldwide have proven that TVOCs are harmful to human health (Fig. 13). They can also enter the body through the respiratory system, by ingesting contaminated food or water, or through direct contact with the skin.

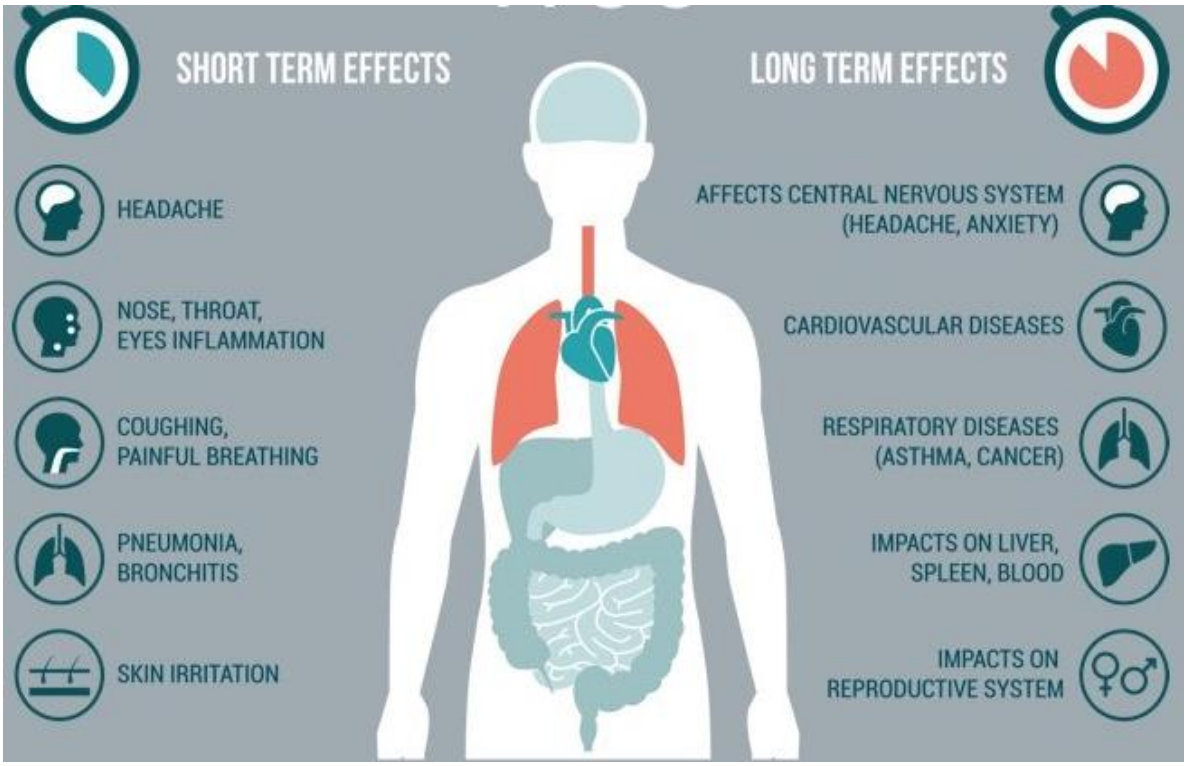


Figure 13. Effects of TVOC on human health

(*Source: https://vn-eco.com.vn/kien-thuc-moi-truong/tvoc-la-gi-anh-huong-cua-chung-toi-suc-khoe-nhu-the-nao/*)

The WHO has listed formaldehyde (HCHO) as a harmful chemical to human health, with the potential to cause cancer because the human body has no mechanism to eliminate this compound (Ministry of Health, 2018).

- Short-term cause of eye irritation, tearing, headaches, difficulty breathing, and throat irritation.
- Long-term external cause of serious skin damage, respiratory system damage, and various blood diseases.
- For pregnant women, exposure to this compound cause of chromosomal abnormalities and malformations, severely affecting fetal development.
- Long-term consumption of food containing this chemical can lead to risk of toxicity and cancer. Formaldehyde has long been listed as a prohibited substance in food processing.

4. PROPOSALS FOR REDUCING POLLUTION

4.1 General solutions

Technical:

- Planning the public transportation network combined with modernizing infrastructure (personal vehicle parking lots, walkways, passenger pickup/drop-off points, priority lanes, etc.).
- Implement synchronized restrictions on personal vehicles and encourage the use of public passenger transport.

Financial:

- Allocate city budgets to support through financial aid or tax/fee reductions for residents when switching from gasoline motorcycles to electric motorcycles,
- Offer discounts on parking fees and tolls for electric motorcycles compared to gasoline motorcycles.
- The same applies to other public transportation.

4.2 Policy solutions

- Synchronized planning of transportation infrastructure network (bridges, intersections, overpasses, signaling, intelligent transportation systems) combined with strong development of public transportation system (both in quality and quantity) using green vehicles.
- Develop stricter policies for gasoline motorcycles; enact standards, regulations, and legal frameworks to facilitate the use of green vehicles by residents.
- Prioritize public transportation by supporting ticket prices, personal vehicle parking lots, pickup/drop-off stations, safe pedestrian infrastructure, priority lanes, toll discounts, and charging stations.
- Create a specific roadmap to support individuals, households, and businesses in transitioning to green transportation at various levels: encouragement, support, and incentives.

- Implement mechanisms and policies to encourage electric vehicle manufacturers through tax and fee reductions, financial support (prices, taxes) for vehicle exchange.
- Establish standards, regulations, and legal frameworks to enable convenient and safe use of electric vehicles, especially regarding fire safety and battery, and waste disposal.
- Diversify communication channels and enhance media efforts to change public awareness towards limiting the use of personal vehicles and transitioning to green vehicles to reduce environmental pollution.

4.3 Specific actions for Cần Thơ City

- Pilot 100% electric vehicles in certain urban areas to gradually raise public awareness. Arrange motorcycle parking lots, allowing only green vehicles in these areas (Ninh Kiều Wharf, Sông Hậu Park, Phong Điền District center - ecological urban area).
- Encourage universities to set up parking lots at school gates, using electric vehicles to transport students to classrooms.
- Implement green transportation days for public servants to create a core group using public transport.

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