

Report on the State of the Environment of Macao 2001



環境委員會
CONSELHO DO AMBIENTE

REPORT ON THE STATE OF THE ENVIRONMENT OF MACAO 2001

Jointly prepared by the Environment Council of Macao and the General Directorate for the Environment of Portugal under the provisions of the Co-operation Agreement between the two entities signed on the 15th April 1999.

ENVIRONMENT COUNCIL OF MACAO (Conselho do Ambiente)

Vong Man Hung	Acting President of the Executive Committee of the Environment Council
leong Kin Si	Senior Officer
Fong Weng Chin	Senior Officer

GENERAL DIRECTORATE FOR THE ENVIRONMENT OF PORTUGAL (Direcção Geral do Ambiente)

Maria Leonor Gomes	Head of Information Department
Nélida Miguens	Advisor
Margarida Marcelino	Principal Officer
Catarina Freitas Alves	Consultant
Vitor Góis	Consultant

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Administration of Airports Ltd.(Administração de Aeroportos, Lda.)
Civil Aviation Authority (Autoridade de Aviação Civil de Macau)
Economic Services Bureau (Direcção dos Serviços de Economia)
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Hovione Macao Ltd. (Hovione Macau Sociedade Química Lda.)
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Macao Electric Company Ltd. (Companhia de Electricidade de Macau, S.A.R.L.)
Macao Productivity and Technology Transfer Centre (Centro de Produtividade e Transferência de Tecnologia de Macau)
Meteorological and Geophysical Bureau (Serviços Meteorológicos e Geofísicos)
Mapping and Land Registry Bureau (Direcção dos Serviços de Cartografia e Cadastro)
Office for Infrastructures Development (Gabinete para para Desenvolvimento de Infraestruturas)
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Provisional Municipality of the Islands (Câmara Municipal das Ilhas Provisória)
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Statistics and Census Services (Direcção dos Serviços de Estatística e Censos)
The Macao Water Supply Company Ltd. (Sociedade de Abastecimento de Água de Macau, S.A.R.L.)
University of Macau (Universidade de Macau)

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Opening Note



The gradual improvement of the living quality of the population is one of the objectives contemplated in the Action Plan of the Government of the Macao Special Administrative Region. Therefore, commitment and efforts are necessary to improve the social and urban facilities, of which environmental protection is one of the indispensable undertakings.

Besides the active participation and cooperation of citizens and of people from different social classes, the implementation of appropriate and effective measures is also an important element of environmental protection work. Then, the execution of studies and the data collection and analysis on the state of the environment provide valuable references for the government in preparation and implementation of such measures.

Based on the research and studies carried out last year, the Environment Council completed in publishing the Report on the State of the Environment of Macao 2001, in which data and information on different environmental aspects are being analysed. This enables us to increase our understanding on the environment and also to supply critical reference information for the government when drawing up policies.

I would like to take this opportunity to express my cordially gratitude to the staff that has been enthusiastically participating in the making of the Report on the State of the Environment of Macao 2001 and to the cooperation of relevant departments and organizations.

Secretary for Transport and Public Works,

Ao Man Long



Sustainable development has become an important ideology of the environmental policy of countries in the world. Human beings have realized that they have to change their behaviour and life style when they consume the natural resources, hence not compromising the needs of future generations.

Macao is now moving towards a “Sustainable City”. The elaboration of the Report on the State of the Environment of Macao just fulfils the needs of the public on local environmental information. Meanwhile, the report will be published in three languages so as to facilitate exchanges with other regions. The increasing number of institutions providing information and the number of persons obtaining the report reflect the growing attention of the public to the state of the environment and this is also what we are expecting. In addition, I would like to deliver my gratitude to those who had presented their professional suggestions and constructive criticism to this report.

In Macao, the government and private institutions are currently engaged in several major projects to promote economic development and tourism. As the city is undergoing further development, we believe that the Report on the State of the Environment of Macao will act as a tool of analysis on the environment. Concluding the present and looking forward to the future, the Report on the State of the Environment of Macao continues to provide valuable references on environmental considerations and relevant policies.

President of the General Committee of the Environment Council,

A handwritten signature in black ink that reads "Vai Tac Leong". The signature is fluid and cursive.

Vai Tac Leong



The Report on the State of the Environment of Macao 2001 concludes the environmental situation of the Macao Special Administrative Region in the first year of the new century. With the past experiences and valuable opinions from the last two reports, the Environment Council utilizes different important indicators of sustainable development to reflect the environmental state of Macao. In addition, more information and data regarding local and global environmental problems are also mentioned to enrich the quality of the report.

The elaboration of the Report on the State of the Environment of Macao 2001 is an essential task for Environment Council. Through collection, sorting, analysing and concluding the environmental databases and information, we can understand better the local environment. Meanwhile, it also gives an important reference to the future policies on sustainable development.

We would like to deliver our sincere gratitude to the contributions of various government departments, private institutions and the General Directorate for the Environment of Portugal for the publication of this report.

Environment Council is looking forward to the constructive criticism to continuously improve the quality of the report.

Acting President of the Executive Committee of the Environment Council,

A handwritten signature in black ink that reads "Vong Man Hung". The signature is written in a cursive, flowing style.

Vong Man Hung

I. Introduction

The publishing of the third Report on the State of the Environment (SoER) of Macao signifies the maturity of the report's content and reflects the acceptance of the community, who not only concerns the environmental problems but also the sustainable development of Macao.

This report is designed to be an instrument of diagnosis on the environmental situation and sustainable development, as well as an indispensable tool for planning and policy-making. The best effort has been made so that this report keeps on incorporating all existing and future environmental issues concerned by both the public and the government. These issues, however, are dynamic in nature and is changing with time and environment accordingly.

The concept of sustainable development started to be broadly used worldwide particularly after the United Nations Conference on Environment and Development in Rio de Janeiro in June 1992. It enables policy makers to consider environmental issues when planning economic policy and investigating other problems. This concept also triggers people to have an ever increasing awareness on the need of changing human behaviour and activities when utilizing natural resources in such an equilibrium so as not to compromise the development of future generations.

Many countries and organizations have demonstrated a growing emphasis on the assessment of the performance and implementation of national environmental and sustainable development policies. This helps to determine to what extent the established demands and goals, both at national and international levels, have been accomplished, in an attempt to integrate environment, economy and social aspects.

Indicators have been increasingly used in the assessment process, i.e. they are instruments that allow for an integrated treatment and transmission of technical and scientific information according to the stated objectives so as to identify the objectives in question. Together with benchmarks (standards established to assess the performance of an undertaking according to certain rules and the objectives of effectiveness and efficiency) analysis, it can reflect and evaluate the fulfillment and effectiveness of programmes and policies on the society, within the scope of sustainable development. It also allows for the comparison among other countries and regions on existing global pressures, as well as for the evaluation of trends of its state over the years and the corresponding responses given by governments and citizens. This methodology may prove to be extremely useful as long as an updated database is ensured by associated data providers and is simultaneously available to the various levels of decisions makers.





This year's SoER is again being published under the collaboration of the Environment Council of Macao and the General Directorate for the Environment of Portugal. Utilizing the effective methodology developed in previous experiences, we endeavor to pursue the most recent global development regarding the field. Similar to previous years, environmental indicators are being presented and comparisons are made with the defined targets and objectives of environmental policy.

However, most of the environmental problems result from the pressures of economic activities. A good example is air pollution caused by the transport, industrial and energy generation sectors; another example is water pollution caused by industries, agriculture and the population itself. From the economic viewpoint, it is therefore more efficient and effective to consider environmental issues in any programmes or plans beforehand and integrate them in the planning and formulation of policies. The ultimate objective of such integration is to minimize the adverse environmental impacts caused by economic activities.

The analysis made in the SoER is not circumscribed to environmental issues. It also tries to report on indicators regarding economic activities and on how these have been integrating environmental interests. We believe that this is the only possible way to report so that each sectoral policy does become sustainable.

Figure 1.1 shows some relevant indices on sustainability issues in Macao and an increase of 45% in waste generation over the past seven years ought to be emphasized, as this brings out an understanding environmental management issue. Keeping pace with population growth, water consumption has increased, while with the fall of GDP (due to the Asian financial crisis), energy consumption has fallen. The economic development in Macao (measured by GDP) although not always positively increasing, has been showing some adverse impacts on the environment, which are demonstrated for instance in the aforementioned waste generation and in the emission of greenhouse gases (GHG). All these indicators point out the

need of reviewing and taking more comprehensive management measures, probably in conjunction with other authorities of the Pearl River Delta, as being recommended in previous reports.

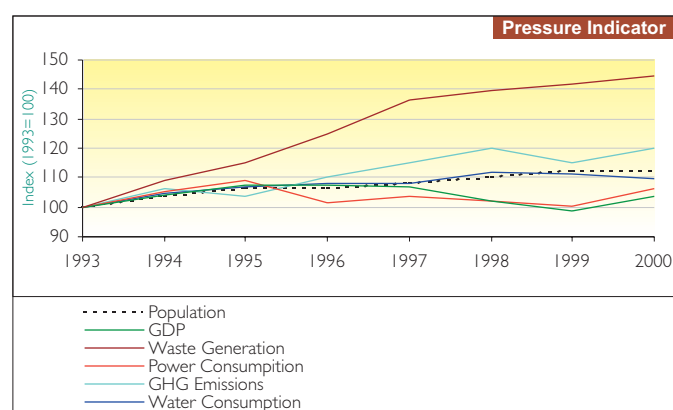


Figure 1.1
Indices reflecting sustainability of Macao

The environmental processes and mechanism are being described in details in this report and a more holistic approach on the assessment of the state has been taken. As opposed to the methodology of utilizing sequential analysis of indicators as of the OECD PSR model (Pressure/ State/ Response) in the SoER 2000, a more flexible and integrated analytical methodology has been used, but also identifying the type of each indicator in the respective figure.

We believe that the periodical review and continuous improvement of the SoER will be crucial for setting up sustainable development policy in Macao, which is something we all wish for.

During the course of last year, the Environment Council has reinforced human resources on the preparation of the SoER. In addition, the work is undertaken through the collaboration of the General Directorate for the Environment of Portugal and the Environment Council of Macao, under the Co-operation Agreement between these two parties.

2. Atmospheric Environment

2.1 Air Quality

The quality of air is usually presented with the use of indicators. These indicators represent the concentration of specific pollutants in a given time frame. The most common polluting indicators are sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO) and total suspended particulates (TSP). These are also classified as primary pollutants due to the fact that they are emitted directly into the atmosphere. There are also other pollutants, called secondary pollutants, such as the tropospheric ozone (O_3), which results from chemical reactions among primary pollutants.

The accumulation of pollutants in the atmosphere depends fundamentally on their emission and existing meteorological conditions. In some instances, these pollutants travel a long distance before they reach the ground and that is the reason why this issue is also the objective of certain international agreements and conventions.

The effects of air pollutants on health and ecosystems depend on the pollutants' concentration and the time of exposure. Long exposure to low concentrations may cause more adverse effects than short exposure to high concentrations. There are also other sensitivity factors to be taken into consideration when determining the extent of adverse effects on humans and these include age, nutritional and physical conditions, or even genetic predisposition. It is, therefore, necessary to carry out assessments to determine the hazards caused by pollution on humans.

The main atmospheric pollution sources caused by human activities are combustion facilities such as thermal power plants, industrial boilers and incinerators, etc. as well as transport and industrial processes.

A summary of the main pollution sources, the interactions and effects of atmospheric pollutants, as well as the consequences resulting from the implementation of emission reduction measures, is shown in Table 2.1 and Figure 2.1.



Table 2.1 - Sources and effects of the most common atmospheric pollutants (Source: SoER Portugal, GDE, 2000)

Pollutant	Main Sources	Effects
Sulphur dioxide (SO ₂)	Natural sources: Volcanic activity Human factors: Combustion of fossil fuel (energy production and industrial sectors), also emitted in small quantities by diesel-engines	<ul style="list-style-type: none"> • Irritation to eyes and respiratory tract with mucous membranes • Worsening of cardiovascular diseases. • Acidification of water and soil and damage of vegetation. • Elevated concentrations may cause changes to the metabolism of plants, such as slowing down their growth rate and photosynthetic rate. • It corrodes buildings and construction materials through the deposition of dry and wet SO₂ and of sulphur aerosols.
Nitrogen oxides (NO _x)	Natural sources: Microbic transformations in soils and electric discharges in the atmosphere. Human factors: Fuel combustion in industrial plants and motor vehicles at high temperatures; the NO _x emitted into the atmosphere is later being transformed into NO ₂ through photochemical oxidation in most situations.	<ul style="list-style-type: none"> • They may cause reversible or irreversible damage to the bronchi and lung alveoli. • They may also increase reactivity to allergens from natural sources. • They may cause lung oedema when in high doses and chronic bronchitis and emphysemas when in low doses. • They cause adverse effects on vegetation when in high concentrations, as well as damage in leaves tissues and growth reduction. • Elevated NO_x concentrations in the atmosphere cause damage on materials especially the natural and synthetic polymers. • Normal concentration of NO in the atmosphere is not considered as a dangerous pollutant.
Carbon monoxide (CO)	Natural sources: Volcanic eruptions and decomposition of chlorophyll. Human factors: Forest fires, incomplete combustion of fossil fuel and other organic materials; road traffic is the major sector that contributes to the emissions of this pollutant. It may also be formed by the oxidation of organic pollutants, such as methane.	<ul style="list-style-type: none"> • It has the capacity of irreversibly combining with haemoglobin (210 times above that of oxygen), giving place to the formation of carboxyhemoglobin. This situation may cause respiratory problems and asphyxia and whenever 50% of haemoglobin is changed into carboxyhemoglobin, it may be fatal. • Affecting visual and working abilities, sensitivity of touch, learning abilities and of performing complex tasks.
Suspended particulates	Natural sources: (Particulates existing in the atmosphere); volcano eruptions, marine mist and wind erosion on the soil. Human factors: Fossil fuel combustion, industrial processes and road transport. Particulates in the atmosphere are considered as primary pollutants as they are directly emitted from polluting sources; or as secondary pollutants when they are formed in the atmosphere through the condensation of gases or as a result of chemical reactions among other pollutants, such as SO ₂ , NO ₂ , VOC _s and NH ₃ .	<ul style="list-style-type: none"> • The smaller the particles size, the greater the hazards to health. • Finer particles contain toxic substances (sulphates, nitrates, heavy metals and hydrocarbons) that are being carried into the lower respiratory tract, with acidic pollutants posing the greatest hazard. • In many European cities, PM₁₀ particles (diameter ≤10µm) are the pollutants that are of greatest concern. They relate to all kinds of health problems - nasal irritation, cough, bronchitis, asthma or even death. The finer fraction of these particles may penetrate deeply into the lungs and reach the lung alveoli, causing respiratory difficulties and sometimes permanent damage. These particles can also penetrate into the building very easily. • Fine particles, particularly those emitted by diesel vehicles, are of the magnitude of visible light wavelength and may thus significantly reduce visibility.
Tropospheric ozone (O ₃)	<ul style="list-style-type: none"> • It is the result of a set of complex photochemical reactions, involving volatile organic compounds, nitrogen oxides, oxygen and solar radiation. • It is one of the main components of photochemical smog. 	<ul style="list-style-type: none"> • Irritating to eyes, nose and throat, followed by cough and headache. • It penetrates deeply into the respiratory tract, affecting bronchi and lung alveoli. Its effect may be felt even at low concentrations and short duration of exposure, especially for children. • It causes adverse effects on vegetation and agricultural products, making significant spots on leaves, growth reduction or even destruction of some sensitive agricultural products. • It causes the degradation of numerous materials like rubber, which is used at the windshield wipers of cars.

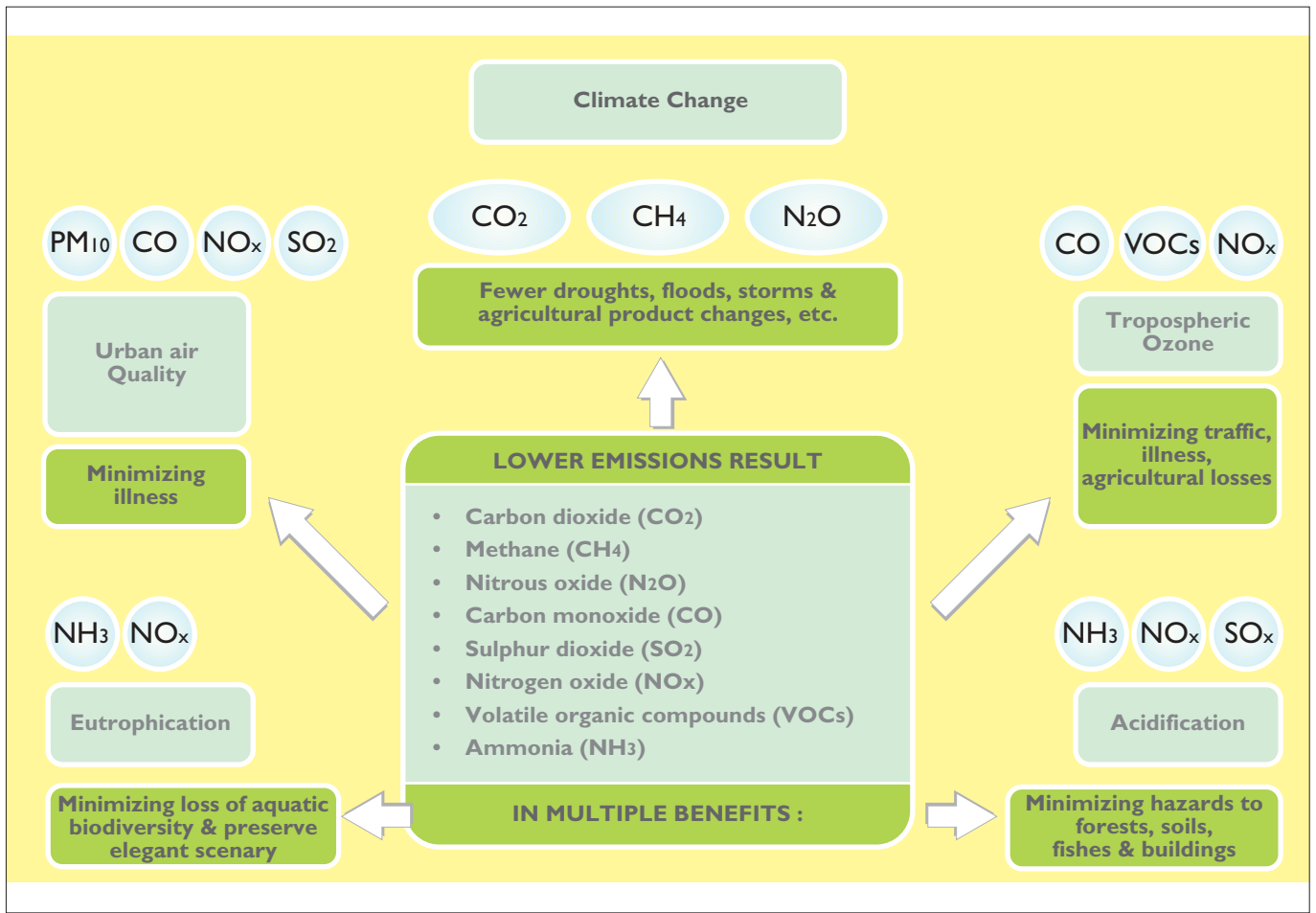


Figure 2.1
Interactions and effects of air pollutants
(Source: SoER Portugal, 1999)

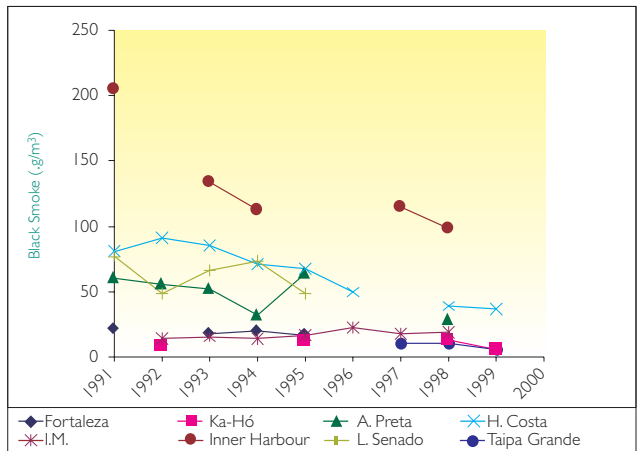
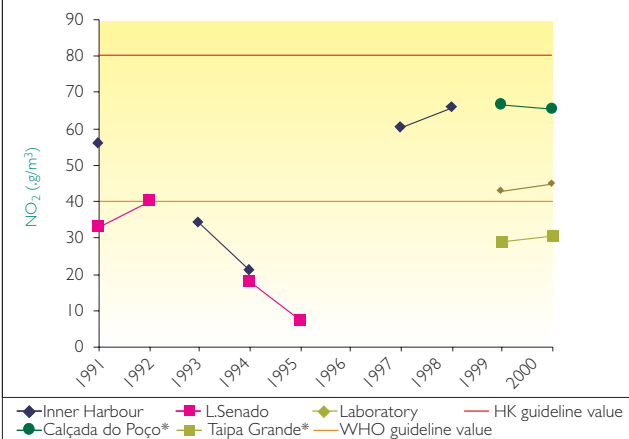
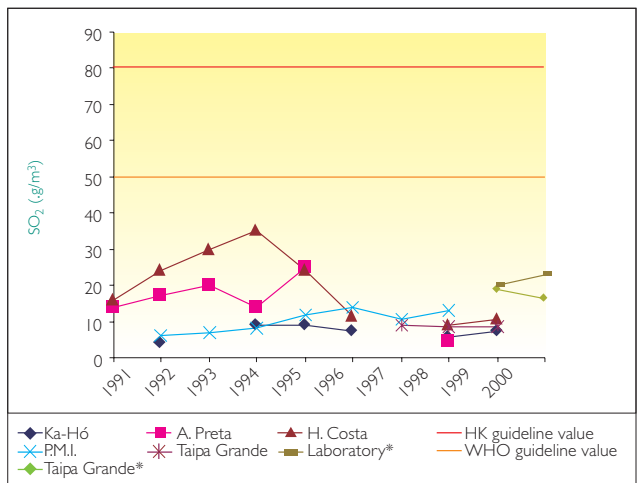
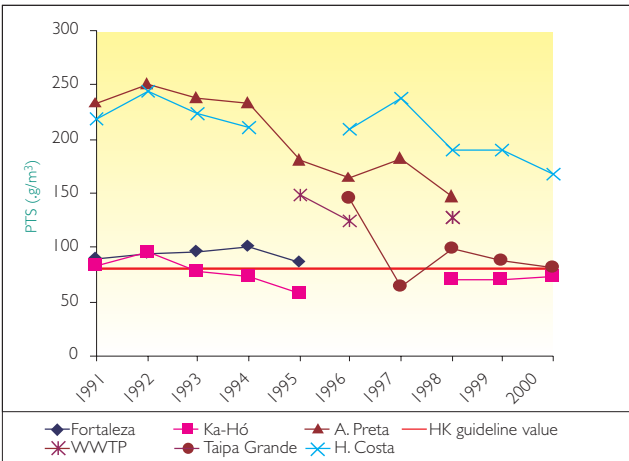
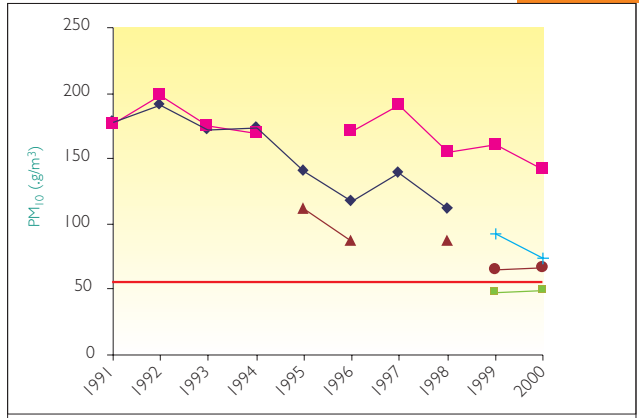
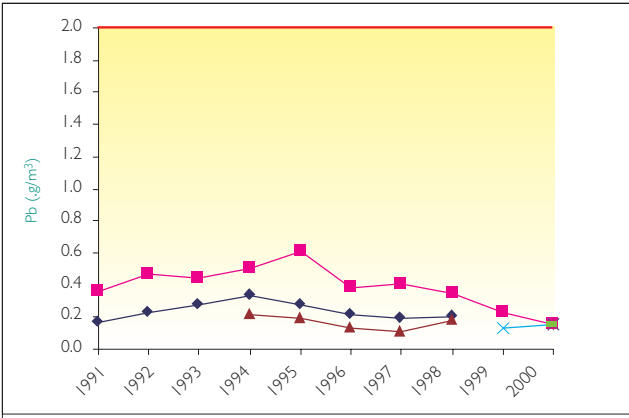
Air pollution affects predominantly in cities like Macao, but the problems are not limited to a certain region. For example, high concentration of sulphur dioxide together with smoke and dust from industrial emissions as well as the suspended particles transported by wind will affect the nearby regions and results in acid rain.

The state of atmospheric pollution over the last decade is monitored by the Meteorological and Geophysical Bureau (MGB) as shown in Figure 2.2 to 2.4. In 1999, the location and numbers of monitoring stations were modified (refer to SoER 1999 and SoER 2000) and **three automatic stations** came into operation. They are located at: **Taipa Grande/MGB Headquarters** (Ambient station), **Municipal Laboratory/North Zone** (Densely populated station) and **Calçada do Poço/Rua do Campo** (Roadside station). Another new densely populated station is located at the roof of the subsidiary elementary school of the University of Macau at Taipa, which came into operation in April 2001. In Figure 2.2, it shows comparison of the annual mean values of local air pollutants with the recommended limit values of international entities (e.g. WHO and EU) and Hong Kong.

It is worthwhile to notice the high values of suspended particulates and the low values of pH. Although there are pollution source such as production of electricity in Macao (refer to emission inventory), the effects from the emission sources in the nearby regions to the local suspended particulates concentration should not be neglected.



State Indicators



* Automatic stations

Figure 2.2 Annual mean values of atmospheric pollutants (Source: MGB, 2001)

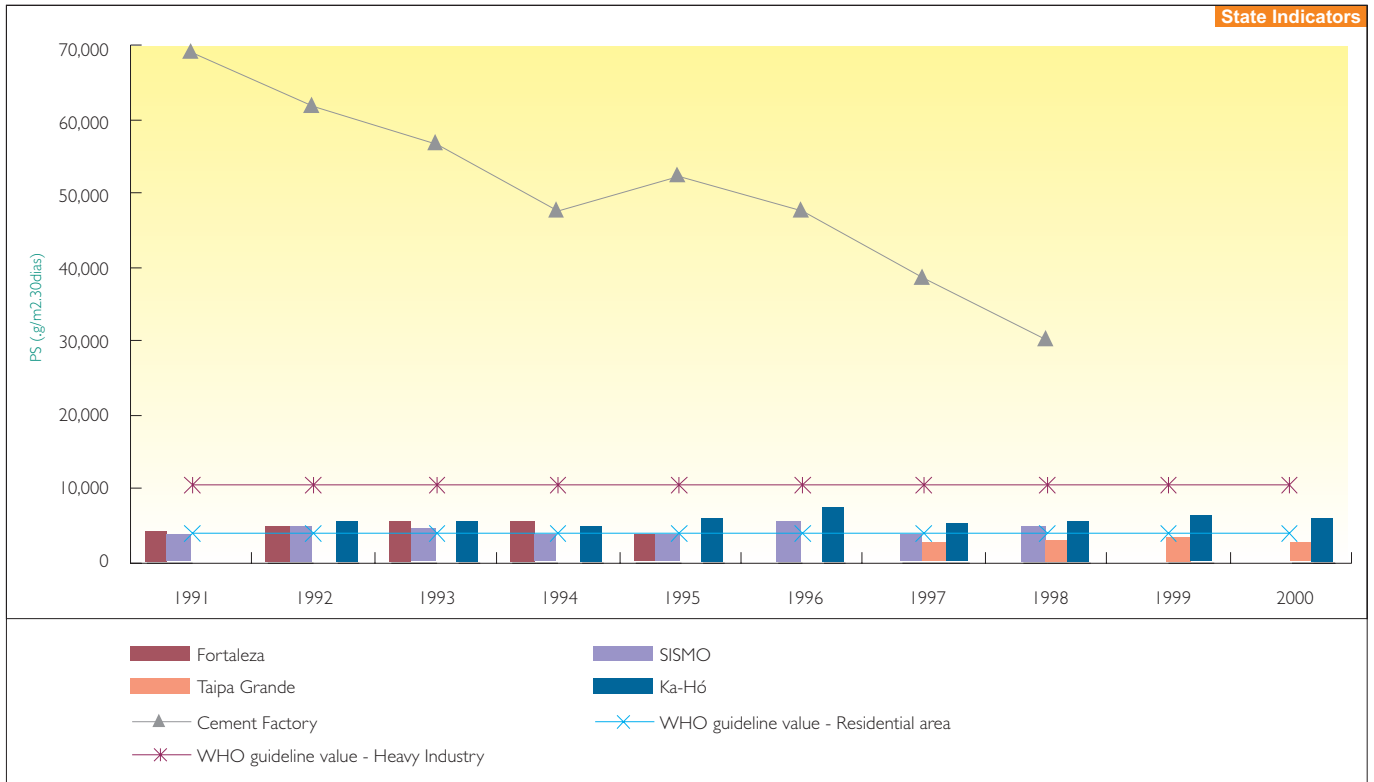


Figure 2.3
Annual mean values of particulates.
(Source: MGB, 2001)

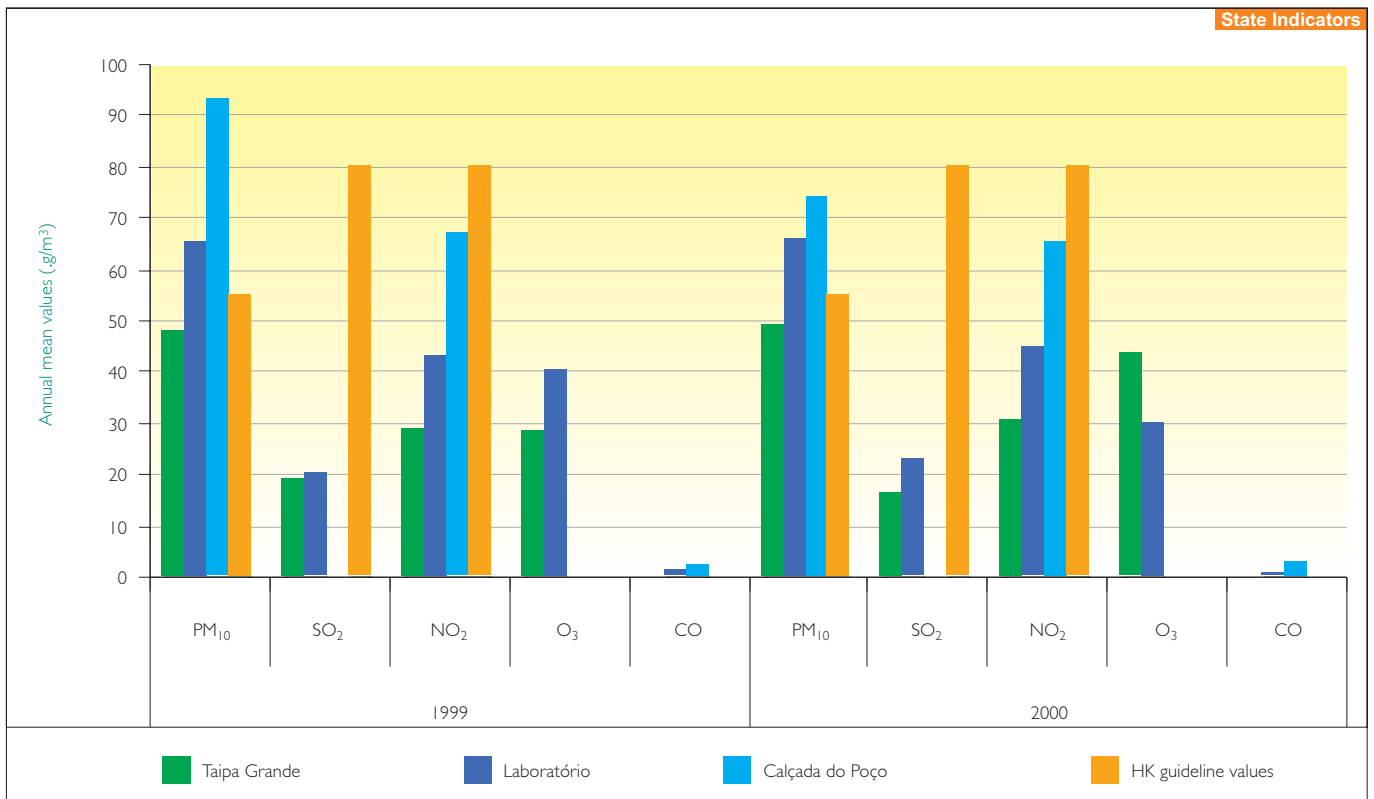


Figure 2.4
Annual mean values of atmospheric pollutants recorded in automatic-monitoring stations.
(Source: MGB, 2001)







The MGB defines the air quality index based on the monitoring of PM₁₀, SO₂, NO₂, CO, O₃ and other pollutants' concentration and the extent of these pollutants towards human health. Index below 100 means that the air quality of a given station is normal while index over 100 means that human health may be affected (refer to SoER 2000).

In 2000, the AQI shows the occurrence of undesirable situations of unhealthy air. However, the air conditions of some polluted districts such as the intense traffic roads cannot be reflected by the AQI. This indicates that it is necessary to monitor the polluting conditions due to traffic.

If an analysis is made on variation of the monthly average of AQI each year, it is found that the majority of pollutants' concentration is comparatively low during the wet seasons (April to September). This shows that the pollutants' concentration is greatly affected by the meteorological conditions of Macao, for example the influence of stable atmosphere in winter months and the strong vertical atmospheric movements in summer.



Table 2.2 - Classification of air quality indices and their effects on human health (Source: MGB, 2001)

Index	Classification	Effects on human health	Recommendations	Visual Aspect
0 ~ 50	Good	No implications.	Normal activities.	
51 ~ 100	Moderate	In case of exposure for long periods, effects on health may occur.	No special prevention measures necessary, except for long duration exposure.	
101 ~ 200	Unhealthy	The health conditions of people suffering from diseases of the cardio-respiratory system may be slightly deteriorated. People with normal health conditions may feel discomfort.	People suffering from diseases of the cardio-respiratory system should reduce any physical strain and avoid open-air activities.	
201 ~ 300	Very unhealthy	The health conditions of people suffering from diseases of the cardio-respiratory system may be slightly deteriorated. People with normal health conditions may feel discomfort.	Physical strain should be reduced to a minimum and open-air activities avoided.	
301 ~ 400	Dangerous	Same as above.	Same as above.	
401 ~ 500	Very dangerous	Same as above.	Same as above.	

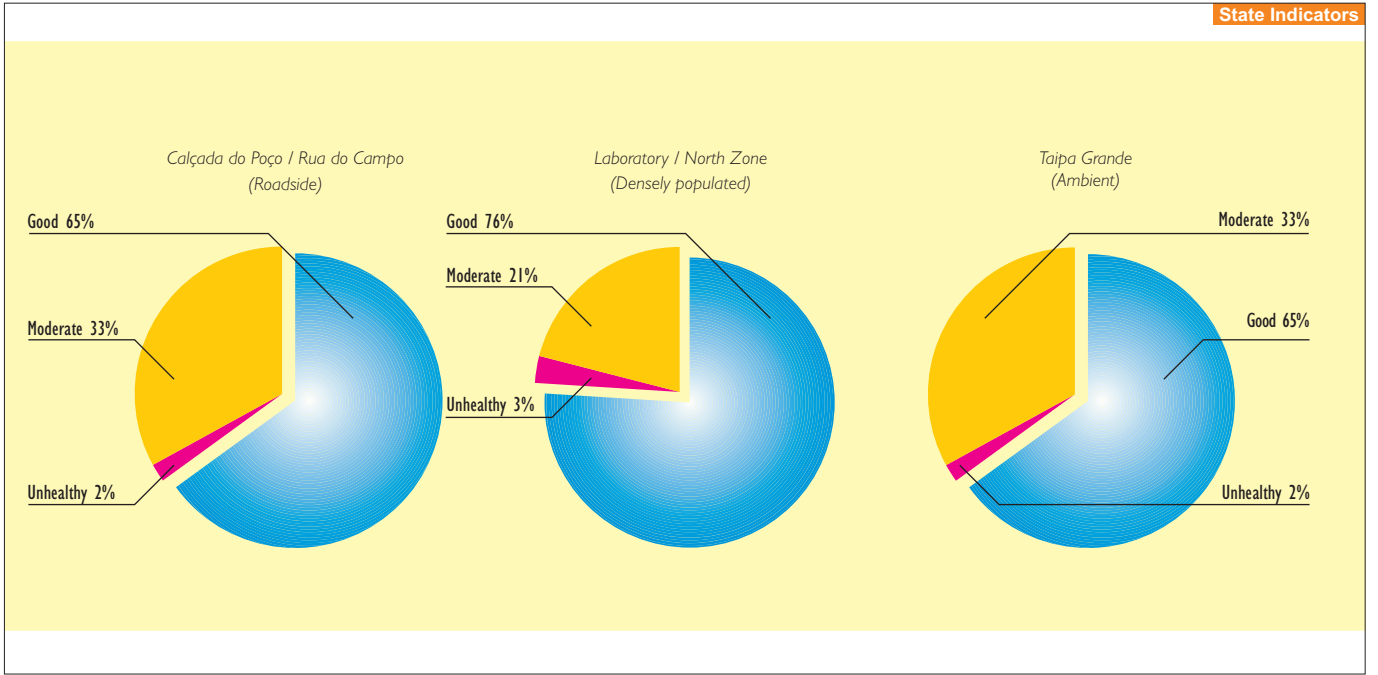


Figure 2.5a
 Percentage of occurrence of different AQI classifications in 2000
 (Source: MGB, 2001)

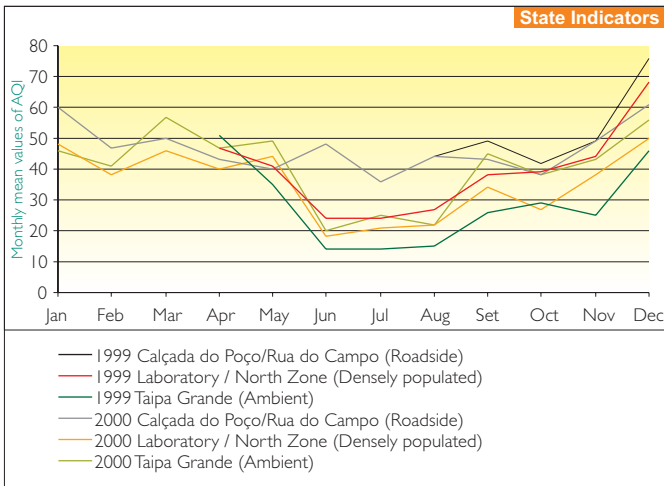


Figure 2.5b
 Monthly mean values of AQI in 1999 and 2000
 (Source: MGB, 2001)



2.2 Atmospheric Emissions

The emission factors of the atmospheric emission inventory of Macao is adapted from EMEP/CORINAIR Atmospheric Emission Inventory Guidebook, IPCC Guidelines for National Greenhouse Gas Inventories, US EPA: "Compilation of Air Pollutant Emission Factors, AP-42" and PARCOM/ATMOS: Emission Factor Handbook. These handbooks are being used since the emission factors are comparatively suitable to the characteristics of Macao. The charts illustrated in this section show the evolution of different pollutants generated by each atmospheric emission in Macao from 1990 to 2000.

Similar to the analysis result shown in SoER2000, the existing data demonstrates that the major pollution sources as a result of human activities are power generation and road transport. As shown in Figure 2.16 the analysis of lead emissions demonstrates that it has been decreasing since the introduction of unleaded gasoline into the market. Besides, the effect of the publication of Executive Order no. 49/2000 on the 7th of August, which limits the sulphur content in light diesel for motor vehicles to 0.05% in weight, will certainly be seen in future inventories.

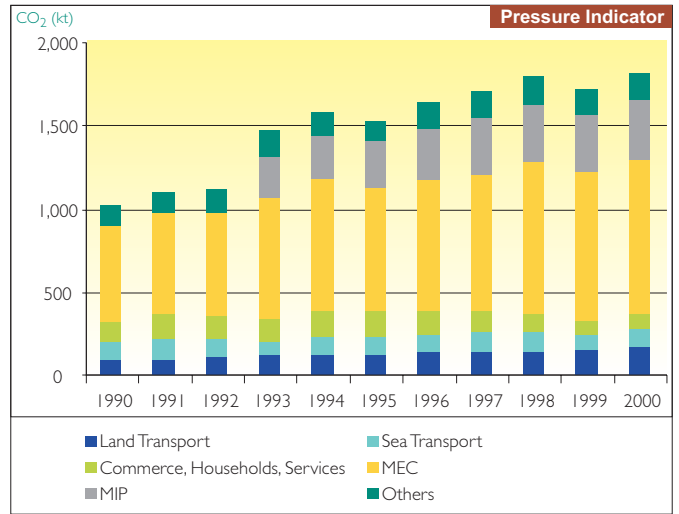


Figure 2.6
CO₂ emissions
(Source: GDE, 2001)

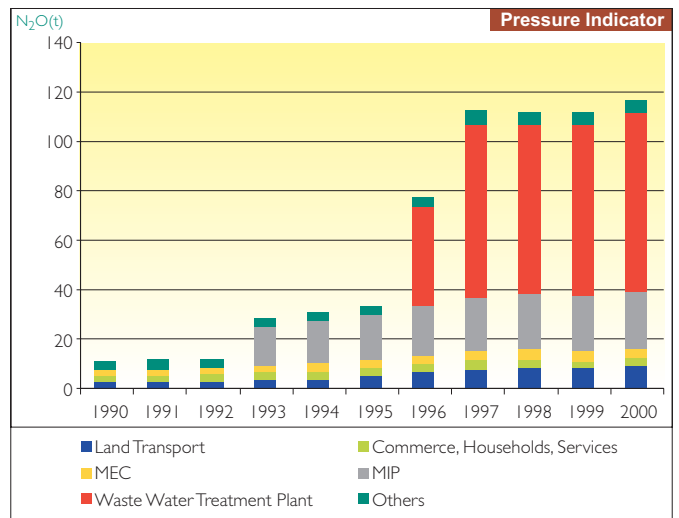


Figure 2.7
N₂O emissions
(Source: GDE, 2001)

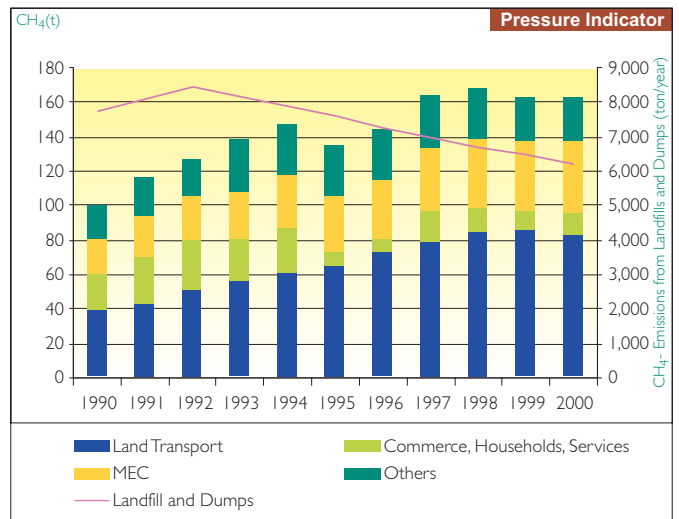


Figure 2.8
CH₄ emissions
(Source: GDE, 2001)

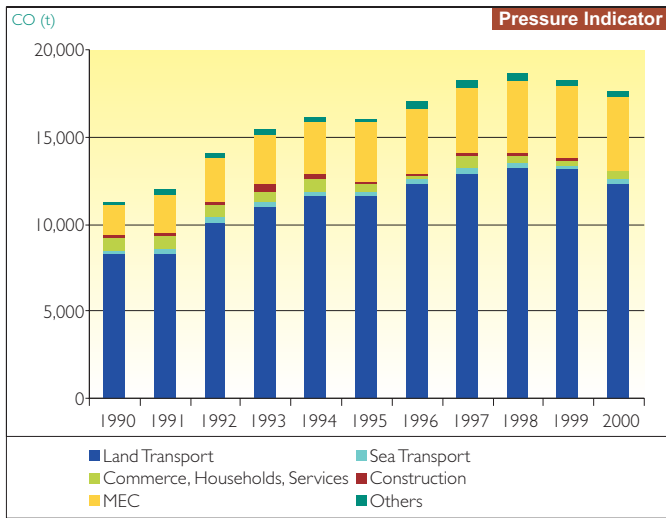


Figure 2.9
CO emissions
(Source: GDE, 2001)

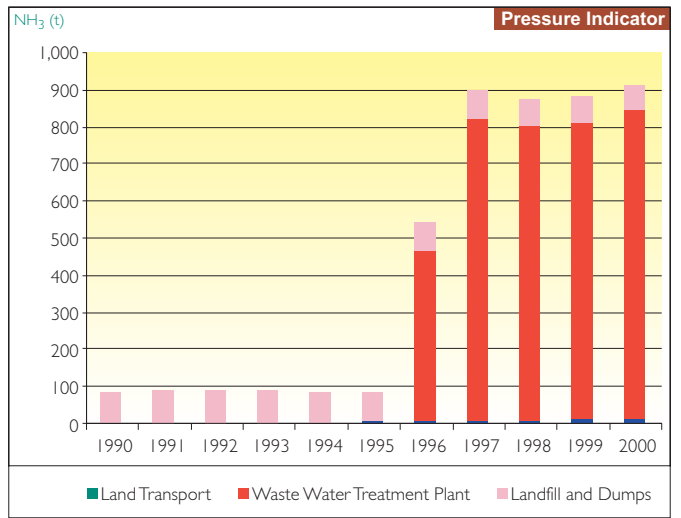


Figure 2.12
NH₃ emissions
(Source: GDE, 2001)

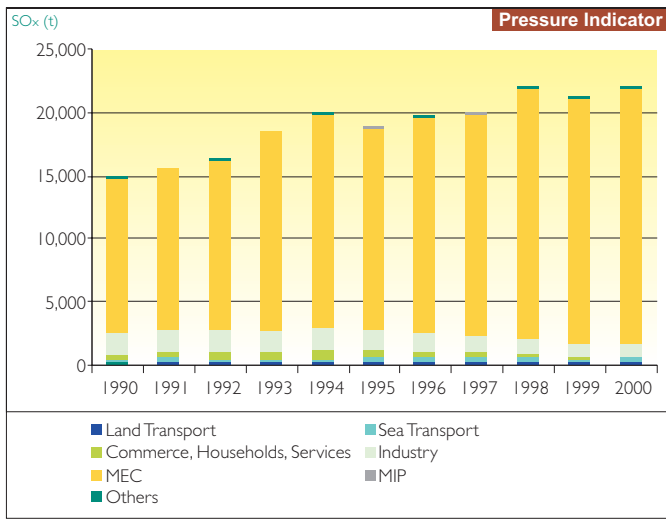


Figure 2.10
SO_x emissions
(Source: GDE, 2001)

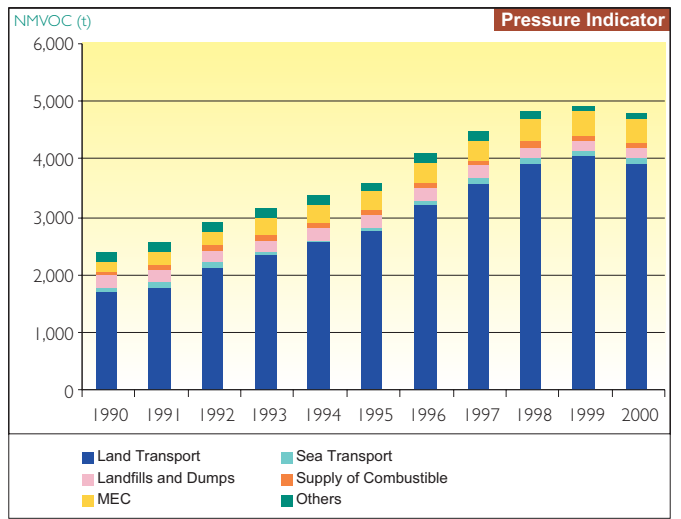


Figure 2.13
NMVOC emissions
(Source: GDE, 2001)

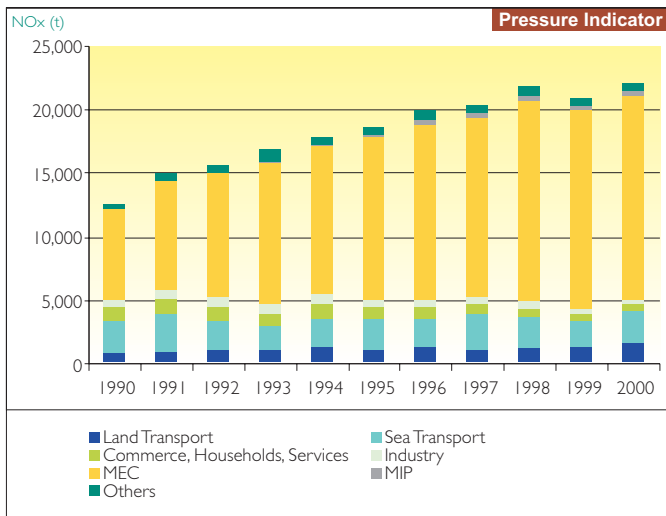


Figure 2.11
NO_x emissions
(Source: GDE, 2001)



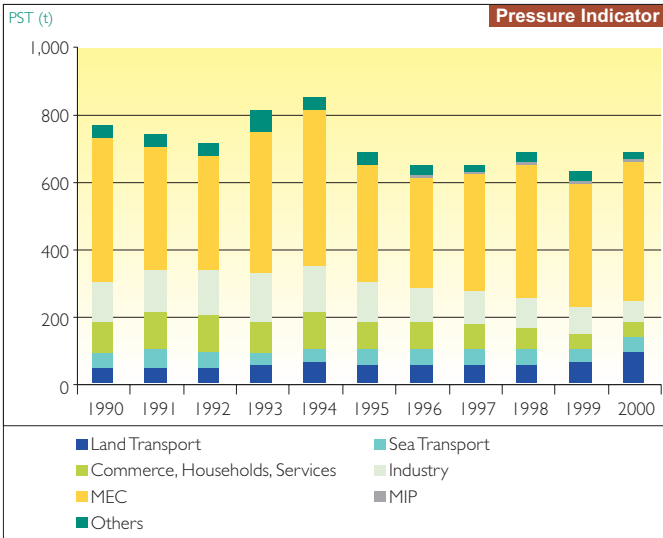


Figure 2.14
TSP emissions
(Source: GDE, 2001)

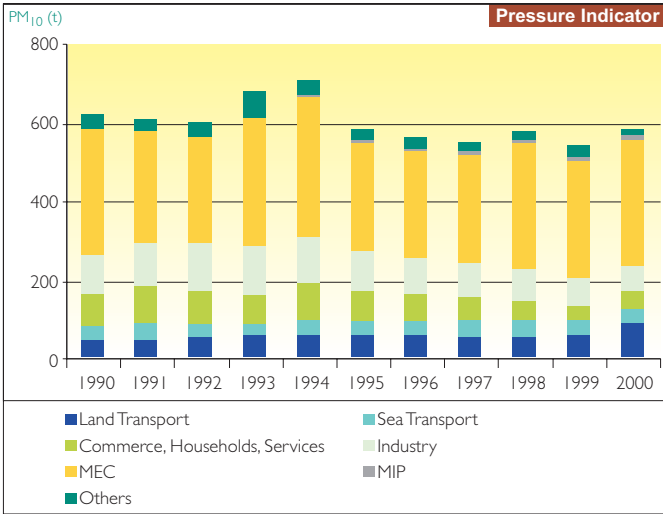


Figure 2.15
PM₁₀ emissions
(Source: GDE, 2001)

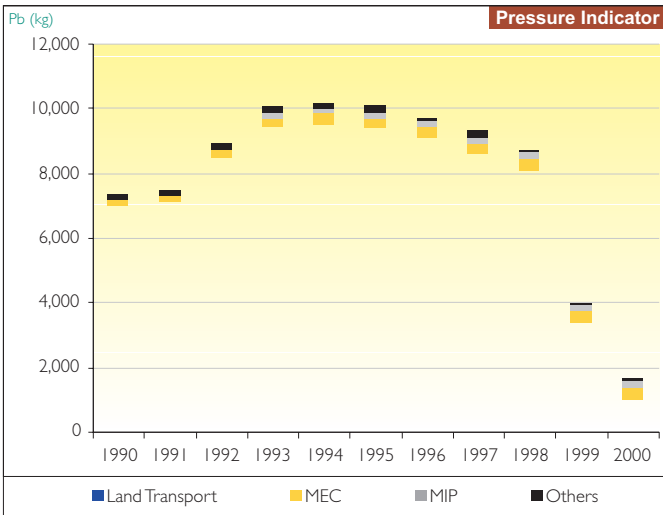


Figure 2.16
Lead Emissions
(Source: GDE, 2001)

2.3 Energy

In the energy sector, due to the fact that Macao has a small geographical area with typical urban features, where people are densely populated and no alternative energy sources can be used (such as wind, solar, hydroelectric and biomass etc., especially the inexistence of the last two natural sources), fuel combustion is used for energy needs. This represents the main source of pollutants emission.

Since 1992, the heat generated by the waste incineration in the Macao Incineration Plant (MIP) is used for the production of electricity. In 2000 about 55 GWh of electric power was sold to the Macao Electric Company (MEC) and this represents 3.7% of the total energy produced in Macao.

Referring to the SoER 2000, the activity of the MEC is the main source of five out of the ten pollutants listed in Macao, namely CO₂, NO_x, SO_x, TSP and PM₁₀. This not only reflects the portion of energy generation over the whole industrial sector of Macao, but also the replacement of steam boilers by diesel engines and the lack of facilities control of exhaust gas. The increase of NO_x, CO₂ and SO_x emissions is associated with the increase of power generation. Figure 2.17 indicates the relationship between the power generation and the emission of the main greenhouse gases (GHG) including CO₂, NO_x and CH₄.

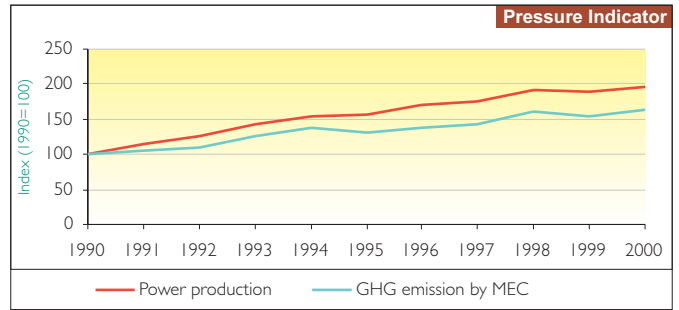


Figure 2.17
Evolution of power generation and GHG emission
(Source: MEC, SCS, 2001)

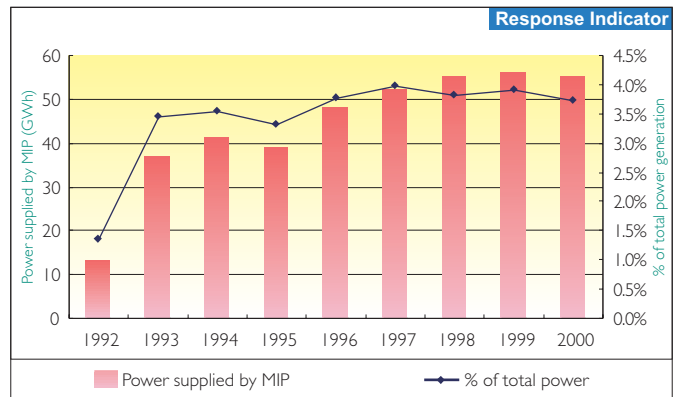


Figure 2.18
Power supplied by MIP to MEC
(Source: MEC, 2000)

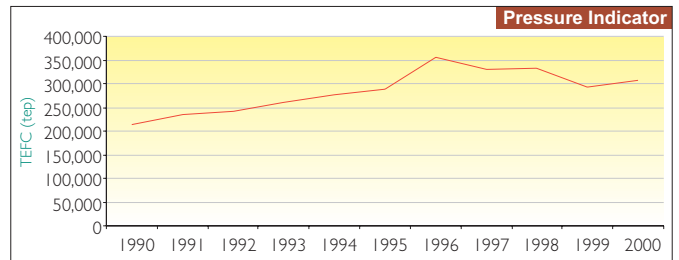


Figure 2.19
Total energy final consumption (TEFC)
(Source: SCS, 2001)

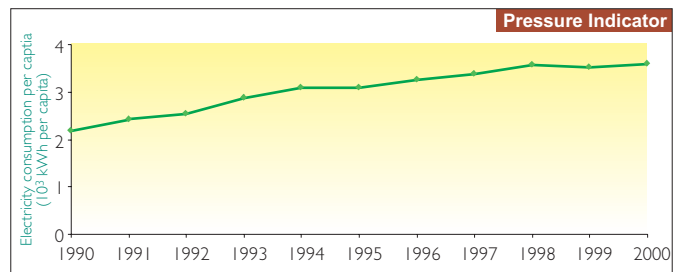


Figure 2.20
Electricity consumption per capita
(Source: SCS, 1990-2001)

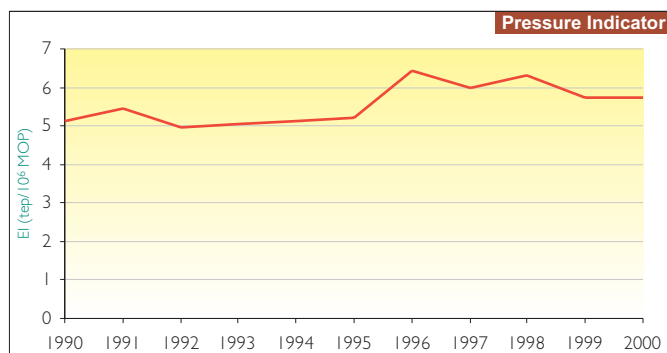


Figure 2.21
Energy intensity (TFC/GDP unchanging prices based on 1996)
(Source: MEC, SCS, 2001)

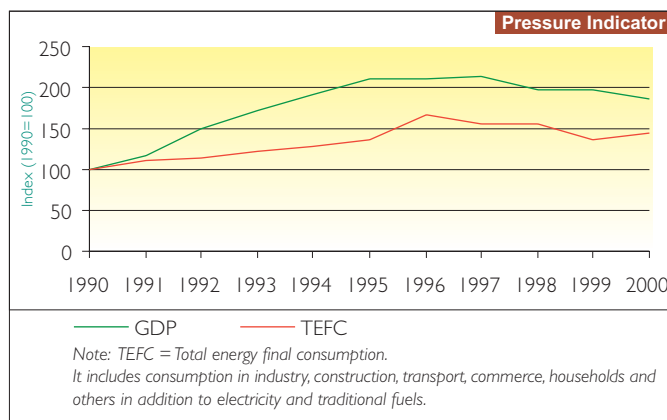


Figure 2.22
Evolution of the total energy final consumption and GNP
(Source: MEC and SCS, 2001)

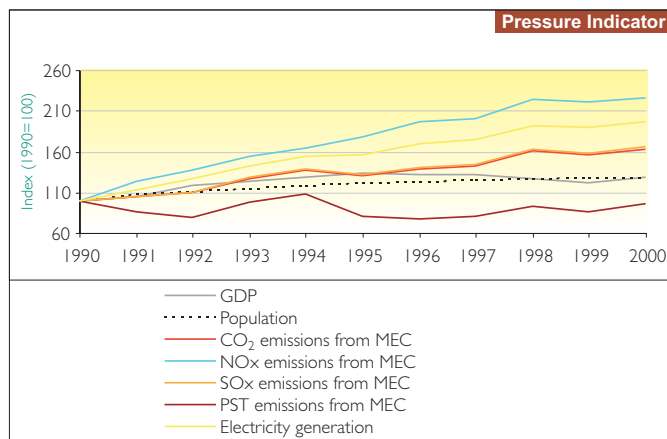


Figure 2.23
Eco-efficiency of the energy sector
(Source: SCS, MEC, GDE, 2001)

2.4 Transport

Transportation brings convenience to people, including a variety of goods and services that makes it essential to the social welfare and economic development of a society. However, transport also exerts adverse effects on the environment, which may deteriorate the quality of life. Over the last decades, a sharp rise in the development of transport has occurred, especially in road transport and this has exerted an enormous pressure on the environment.

In Macao, energy consumption in the transport sector corresponds to about 45% of the total energy consumed in the region (this percentage is calculated without taking into account the consumption of the power generation sector). The transport sector is also evolving, particularly for road transport (Figure 2.24). The large number of motor vehicles in circulation (the majority being privately owned cars) causes unquestionable environmental impacts such as air and noise pollution. The emission and air quality monitoring values (such as CO, N₂O, VOC, CO₂ and PM₁₀) completely demonstrate the situation in this sector.

It is in fact that the technological advances in the automobile industry (such as the introduction catalytic converters and the reduction of sulphur and lead content in fuels etc.) have reduced some adverse effects on the environment (for example particulates, NO_x, VOC and CO emissions). These measures are not, however, enough to compensate the growing traffic intensity. In order to improve the eco-efficiency and safety of transport, it is necessary that policy instruments, such as the regulation of technical aspects, the prices and taxes on fuels and the spatial planning aspects, are applied in such a way that environmental concerns are integrated in transport policies and to bring the so-called “Sustainable mobility” into practice. Educational activities are also being carried out extensively to raise peoples’ concerns to the advantages of a good public transport network and pedestrian zones.



Some measures have already been implemented in Macao in order to alleviate the harmful effects caused by the increasing number of vehicles on the environment, health and quality of life. In 2000, one of these measures introduced by the Provisional Municipality of Macao is the enforcement of notifying the government when people intend to abandon the vehicles so as not to occupy public spaces. Another measure that has been implemented is the increase (about 4-fold over the last ten years) of adequate parking places to avoid inconvenience and obstacles to both pedestrians and drivers caused by illegal parking. Even with all these measures, it is obvious that roads are heavily congested at present.

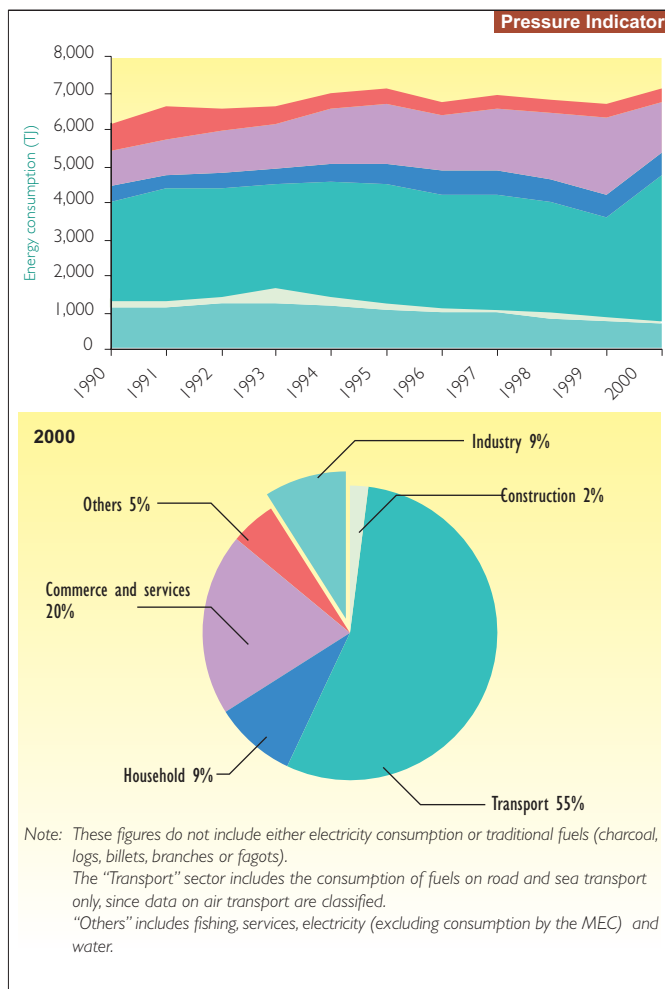


Figure 2.24
Energy consumption by different sectors (excluding MEC)
(Source: SCS, 1990-2001)

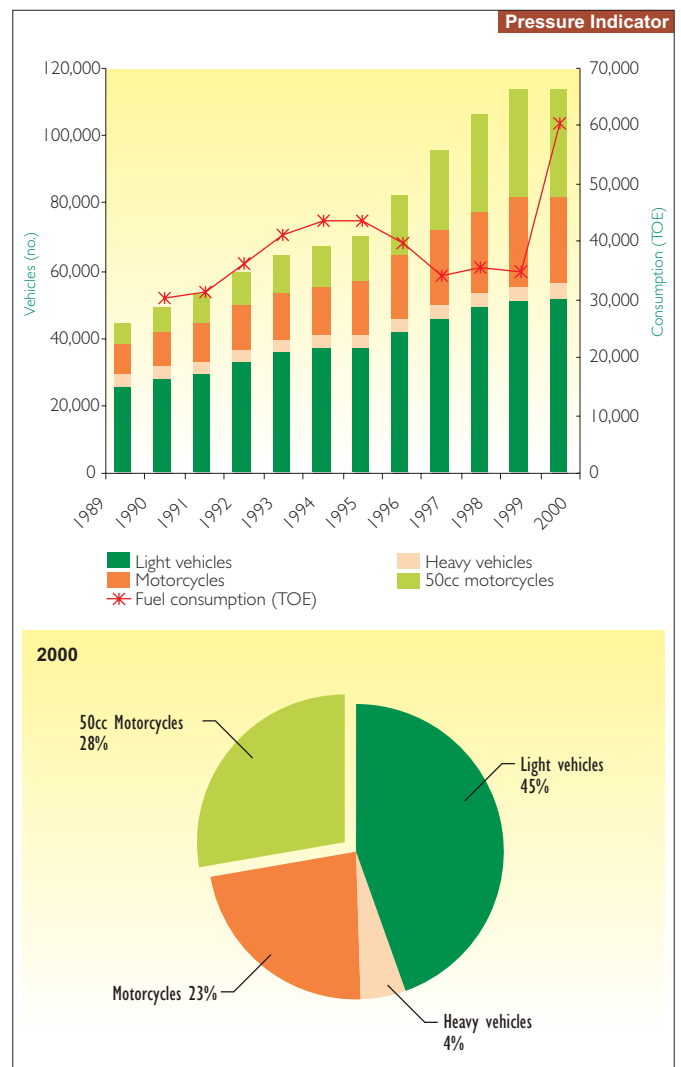


Figure 2.25
Evolution of the number of vehicles in circulation and the corresponding fuel consumption
(Source: SCS, 1990-2001)

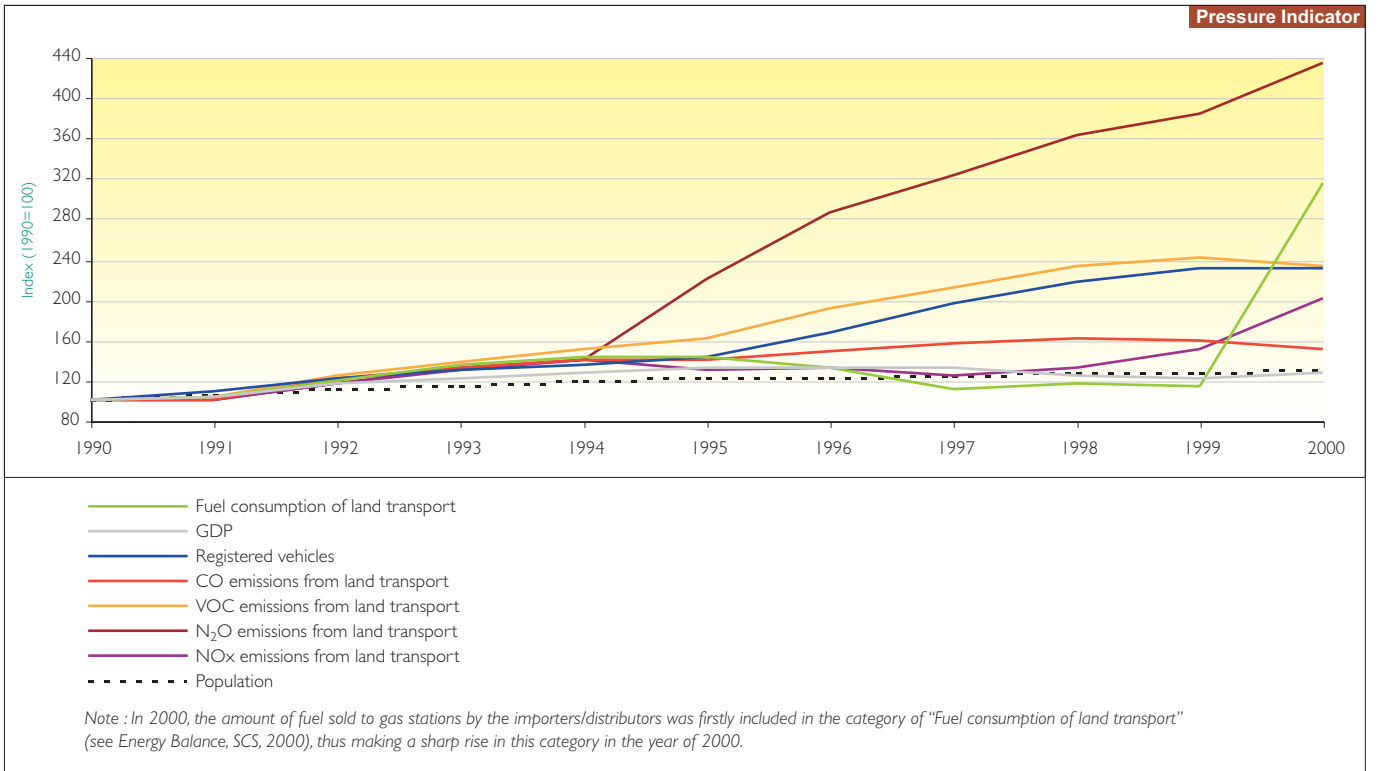


Figure 2.26
Eco-efficiency in the transport sector
(Source: SCS, 1990-2000)

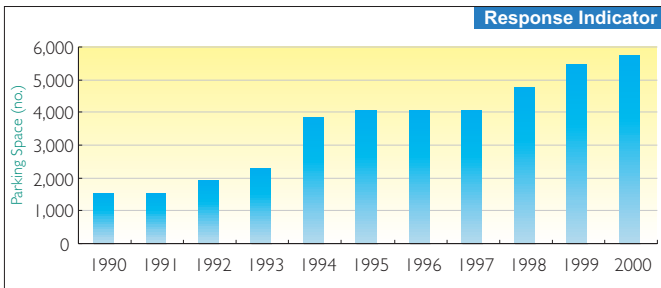


Figure 2.27
Public-parking lots, excluding the 18,515 parking spaces on street curbs
(Source: Lands, Public Works & Transport Bureau, 2001)



2.5 Climate Change

Macao is a member of the Framework Convention on Climate Change and commits to endeavour towards the control of greenhouse gases emission. The department nominated as the contact point for such an important international issue is the Meteorological and Geophysical Bureau.

The phenomena happening in the process of "Climate change" will be explained thereafter, as climate change has attracted the attention of political and scientific sectors all over the world and has also become one of the principal issues in the environment agenda.

Climate change has been occurring on Earth over a long period of time and hence should be considered as a natural phenomenon. However, climate change has accelerated and became a significant issue at global scale. In fact, scientists

generally agree that temperatures on the Earth's surface are increasing over the years and the so far highest temperature was recorded in the year of 1998. Although there has not been any consensus regarding the contribution of human activities to this process, the fact remains that if there has not been 23.4 billion tons of carbon released to the atmosphere by human (OECD, 1999), the warming process would not have accelerated. Approximately 3.4 billion tons of carbon was emitted from the EU each year (EEA, 1999).

Over the last century, concentrations of certain gases continuously accumulate in the atmosphere and they trap part of the infrared radiations releasing from Earth to space. This phenomenon is usually called the "Greenhouse effect" and the gaseous emissions causing this phenomenon are known as "Greenhouse gases" (GHGs). Such effect is causing global warming which is meant to be an increase of the mean surface atmospheric temperatures. Over the last century, the mean surface atmospheric temperature has increased by 0.5 °C.

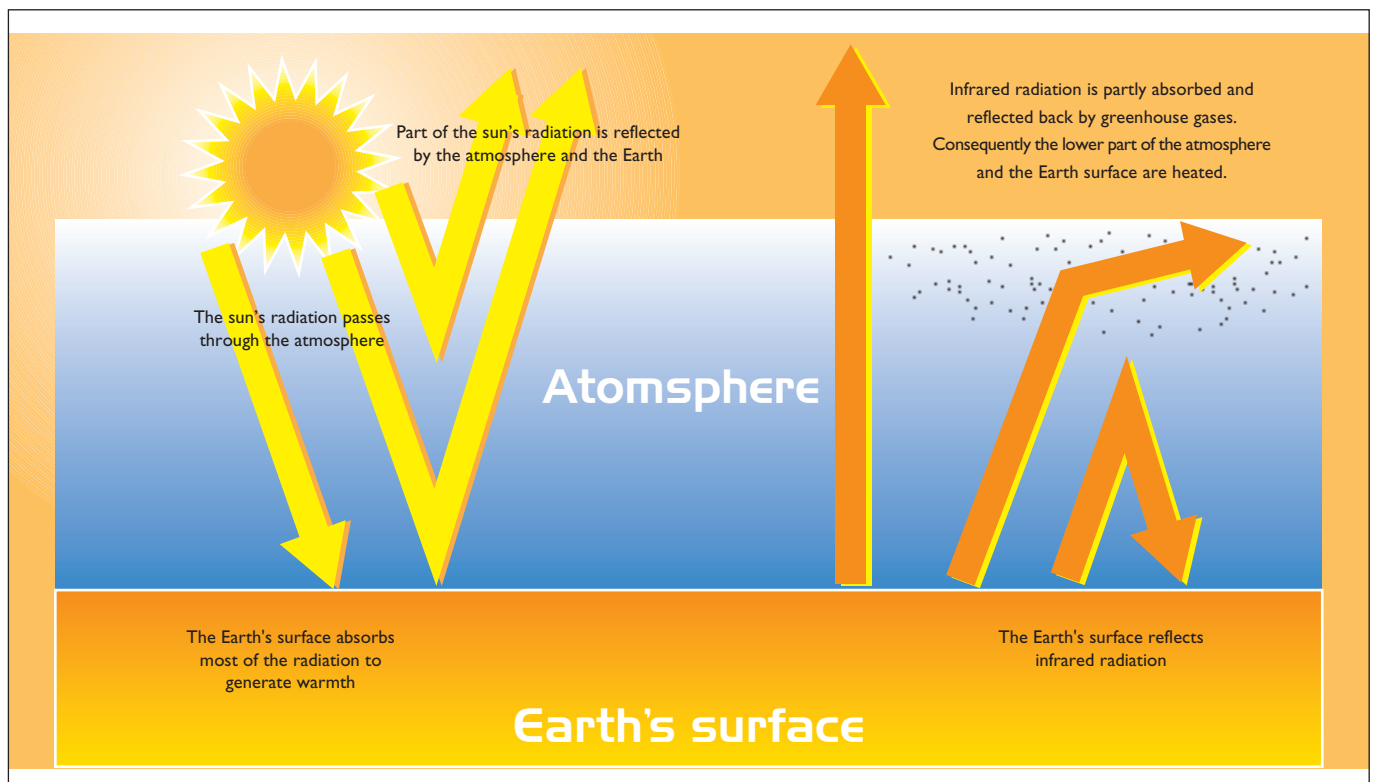


Figure 2.28
Illustration of Greenhouse Effect
(Source: SoER Portugal 1999, GDE, 2000)

Carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and halogenated compounds such as HFCs, PFCs and SF₆ are the gases that most significantly contribute to this effect (GHGs-greenhouse gases). The main human sources of GHG and their respective contribution to global warming are shown in Table 2.3.

Table 2.3 – Main human sources of GHG and respective contribution to the greenhouse effect

Gas	Main Human Sources	Contribution (%)
CO ₂	Energy use, deforestation and alterations to soil use, cement production.	64
CH ₄	Energy production and use, animals, agriculture (rice paddies), landfills, biomass and fossil fuel burning.	20
N ₂ O	Use of fertilizers, acid production, biomass burning and combustion of fossil fuels.	6
Halogenated compounds	Industry, refrigeration, aerosols, propellers, expanded foams and solvents.	10

(Source: EEA, 1998)

For comparison purposes, the emissions of six greenhouse gases are usually expressed in CO₂-equivalent and based on GWP (Global Warming Potential) over a 100-year period. CO₂, CH₄ and N₂O are the greenhouse gases whose emissions are generally taken into account and their GWP are 1, 21 and 310 respectively. This means that CH₄ has a GWP 21 times above that of CO₂ and that N₂O has a GWP 310 times above that of CO₂.

As previously mentioned, Macao is a member of the Kyoto Protocol to the Convention on Climate Change. Though it is not one of the Parties included in Annex I (Parties committed to reduce emissions of each GHG to a certain level in the commitment period of 2008 to 2012), it should nevertheless endeavour all efforts with a view to immediately start reducing the emission of greenhouse gases, which have shown to be increasing since 1990 as illustrated in Figure 2.29.

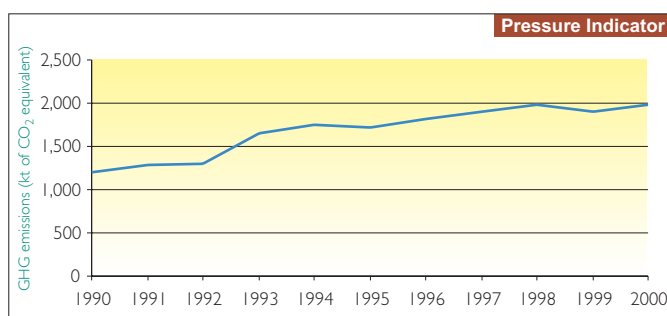


Figure 2.29
Evolution of GHG emissions in Macao
(Source: GDE, 2001)

There are natural CO₂ sinks which positively contribute towards atmospheric CO₂ balance by means of absorbing this gas (as in the case of forests) or by fixing carbon to the soil (as in the case of agriculture). These sinks play an extremely important role towards the reduction or stabilization of CO₂ concentration in the atmosphere.

The consequences resulting from climate change are widespread and according to the European Environment Agency, they can arise phenomena such as:

- rise of sea-level and possible submersion of coastal low-lying areas;
- melting of glaciers;
- changes of the hydrologic cycle and rainfall patterns, with implications of floods and droughts;
- changes in the incidence of climatic extremes, in particular of high temperature extremes.

These effects may cause impacts on ecosystems, health, water resources and key economic development such as agriculture and the extent is still uncertain. There is still the need for the scientific community to clarify the uncertain. Nevertheless, international societies have been implementing preventive policy to minimize the loss.

2.6 Protection of the Ozone Layer

Depletion of the ozone layer is another issue of international significance affecting the stratosphere. This layer is fundamental to protect life on Earth, due to the fact that stratospheric ozone has the capacity to absorb ultraviolet-B radiation (UV-B), which may cause adverse (or even lethal) effects on living organisms. Among such effects, mutations of DNA (main cause of skin cancer), mutations of the immune system (emergence of infectious diseases), as well as the impairment of vision (with the appearance of cataracts) may occur.

Ozone (O₃) is a gas containing three oxygen (O) atoms. About 90% of the ozone exists in the stratosphere, stretching from about 10-50 km above the ground; but the largest ozone concentrations are at altitudes from 15 to 35 km, forming what is usually called the "Ozone Layer".

Stratospheric ozone is produced by the action of ultraviolet solar radiation on oxygen (O₂) molecules, in a process named photolysis: oxygen molecules break apart and originate oxygen atoms, which, in turn, combine with other oxygen molecules forming ozone.

The amount of ozone existing in the stratosphere is maintained in a dynamic balance by the natural processes, through which it is continuously formed and destroyed. However, such a natural balance between production and loss of stratospheric ozone has been disrupted due to anthropogenic emissions of halogenated compounds, such as chlorofluorocarbons (CFCs) and halons.

These compounds are very stable and are not destroyed in the troposphere; therefore, a single chlorine or bromine atom can destroy thousands of ozone molecules before being removed from the stratosphere.

Figure 2.30 explains the mechanism of ozone destruction by the action of one chlorine atom released from one CFC₃ (CFC-11) molecule.

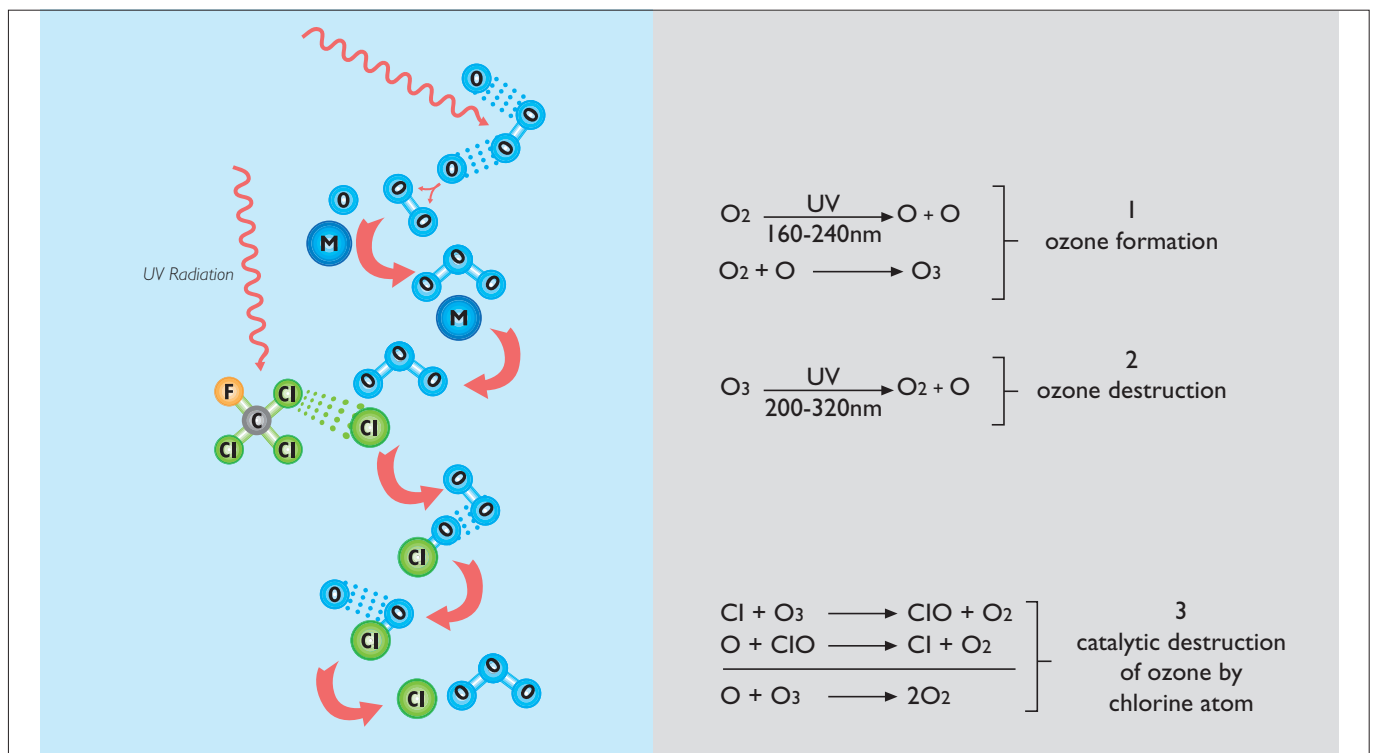


Figure 2.30
Illustration of the ozone molecule destruction
(Source: WMO/UNEP, *The Changing Ozone Layer*, 1995)

Due to the persistence of these compounds, even after implementing several measures with a view of reducing their emissions, various decades will have to elapse before the ozone levels rise again in the stratosphere. In fact, although the use of halogenated compounds has suffered a decline as from the 1980, as a result of the implementation of the commitments assumed through the Montreal Protocol on Substances that Deplete the Ozone Layer to the Vienna Convention (Convention on the Protection of the Ozone Layer) and its Amendments, it is expected that the chlorine and bromine concentration in the stratosphere reached its maximum around 2000 and that only in the year 2060 the ozone layer will have entirely recovered.

Macao is a member of the Montreal Protocol on Substances that Deplete the Ozone Layer. Executive Law no. 62/95 of 4 December is being applied so as to execute the international commitments of the Vienna Convention in Macao. From 1996 (Order no. 78/GM/95 of 4 December), the production of substances that may have implications on the depletion of the ozone layer has been banned.

The Economy Bureau the authority supervising the import and export of substances and equipments (such as sprays, air conditioners, refrigerators, fire extinguishers, etc.) that contain substances that may affect the ozone layer. This department has to inform and request opinions from the Environment Council over certain situation.

Among the chemical substances subject to the reduction measures established in the Executive Law no. 62/95/M, the imports of 1,1,1-trichloroethane are now being controlled as according to Order no. 78/GM/95 and is expected that none will be imported by 2005. The evolution of imports of this compound is shown on Figure 2.31.

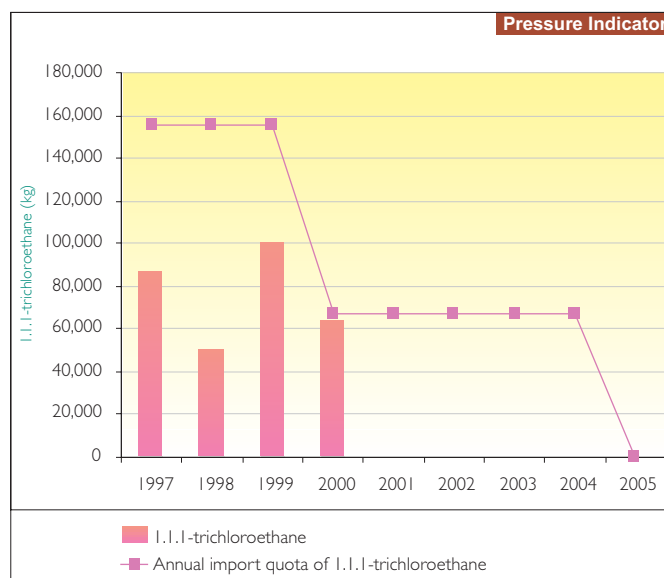



Figure 2.31
Imports and annual quota of 1,1,1-trichloroethane
(Source: EB, 2001)



3. Water Resources

 Water circulates continuously in nature - the natural water cycle or hydrologic cycle refers to part of the precipitated water returning to the atmosphere through evapotranspiration, with the remaining precipitated water returning to the sea by surface runoff and supplementing the aquifers.

About 71% of the planet's surface is covered by oceans, in which the diversity of species, even though small in numbers, is far superior to that existing on land. (43 marine phyla vs. 28 land phyla),

Coast is the interface between ocean and land, where it is of extreme specificity and sensitivity because of its dynamic and relative unstable characteristics. It is also rich in ecological diversity and of great economic value. However, excessive exploitation along the coast might lead to situations where the capacity has been exceeded and adverse impacts become observable. Erosion caused by improper urbanization, the discharge of untreated waste water, the over-exploitation of fisheries leading to species endangerment and the degradation of water quality resulting from water transport are some of the factors that contribute to the deterioration of the marine and coastal environment.

Freshwater resources are essential to human life, economic productivity and social development. Since they are limited

resources, they should be managed in a proper way. As abundant as freshwater may be at global scale, they are scarce in some regions and countries. Several different international organizations have carried out studies, which unanimously consider that the water resources available for human consumption are diminishing.

This is partly due to the fact that many aquifers are being contaminated by human activities.

The multiple uses of water are sometimes contradicting, e.g. human consumption, bathing purpose, industrial activities, power generation and agriculture etc. All these actions require an adjustment between time and space in such a way that each sector can finely adjust and coordinate within itself, enabling directly or indirectly different entities to have a coherent action on planning, management and use of water resources. It is therefore necessary to have an integrated consideration on the management of each water catchments, coasts, aquifers or ocean, and not just considering a location only for abstraction and discharge. Proper management of this valuable resource is indispensable and it is necessary to get hold of the knowledge and technology for adequate treatment of water for human activities (e.g. water treatment plants). At the same time, wastewater should also be treated properly in order to cope with the capacity and standard of the receiving body for subsequent use.

To conclude, all these enable readers to understand that managing both the quantity and quality of the water resources is an important and complicated factor in the formulation and implementation of environmental policy.



3.1 Drinking Water

Water Supply

With a small geographical area and the lack of natural water resources, the availability and the use of fresh water in Macao depends almost entirely on the supply from Madaomen Canal of the mainland. Raw water is extracted from the Madaomen Canal and then conveyed by gravity to a pumping station situated in the mainland. Thereafter, the raw water is being transferred to the Ilha Verde Water Treatment Plant in Macao. Surplus water is delivered and stored in the Outer Harbour Reservoir. In addition, the Seac Pai Van Reservoir, the Ká - Hó Hác Sá Dams collect and store rainwater.

In order to guarantee that the quality of water supply is up to the standards during the saline period, a submerged pumping station with a capacity of 40,000m³/day will be installed at the Outer Harbour Reservoir, which increases the usable portion of the water in the reservoir and the capacity of saline dilution.

Another measure will be the widening and deepening of the Seac Pai Van Reservoir, to a capacity of 2,000,000m³ which is about 90% of the Outer Harbour Reservoir storage volume.

Water Consumption

After being treated at the water treatment plants, water is supplied to the users through the water distribution network.

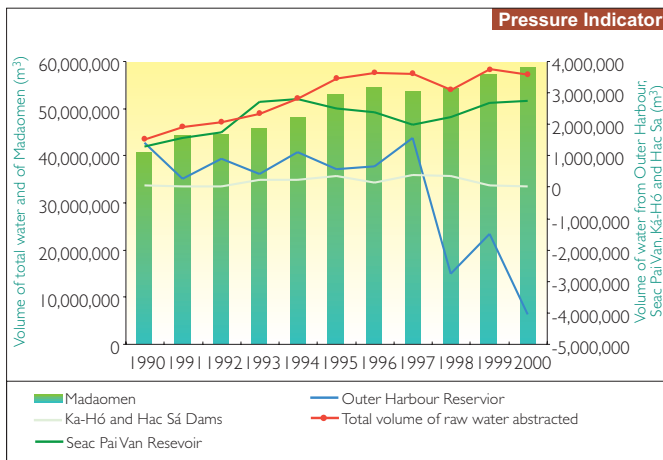


Figure 3.1
Volume of raw water supplied to Macao
(Source: PMM, 2001)

With the fast growth of population in Macao, an increase in the raw water abstraction from Madaomen as well as the amount of water consumption have been observed. This together with the salinity problems occurred during the dry seasons in the past few years make it necessary to utilize the water in the Outer Harbour Reservoir for saline water dilution. Hence, negative values are shown in Figure 3.1 about the storage volume in the Outer Harbour Reservoir.

Since the end of 1999, the Macao Water Supply Company (MWSC), which is responsible for the supply of drinking water in Macao, has appointed a team of expertise to investigate the problem of salinity. The proposed strategy is to relocate the present water abstraction point further upstream of the Pearl River Estuary so as to minimize the possibility of abstracting saline water. At this moment, most of the water abstraction infrastructures are located in Zhuhai and the competent authorities in the mainland and Macao are now evaluating possible solutions.

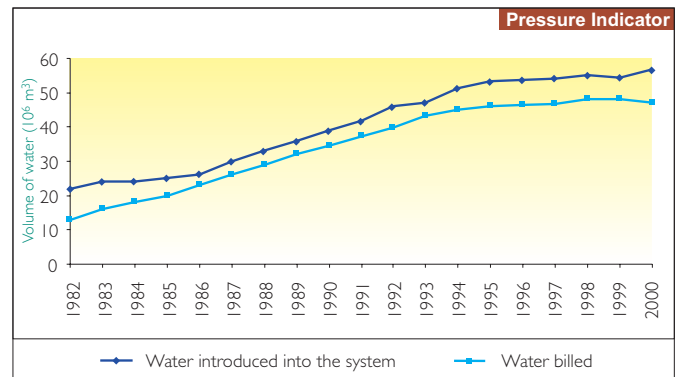


Figure 3.2
Volume of water introduced in the system and billed
(Source: PMM, 2001)

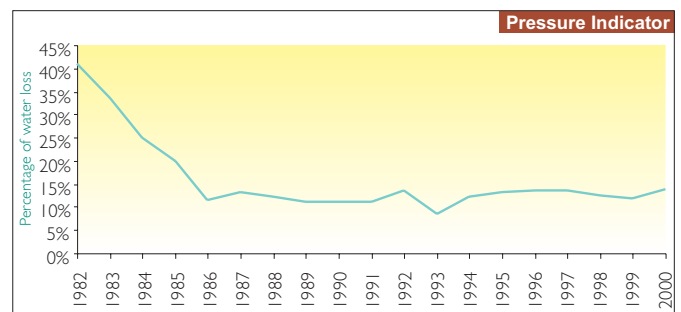
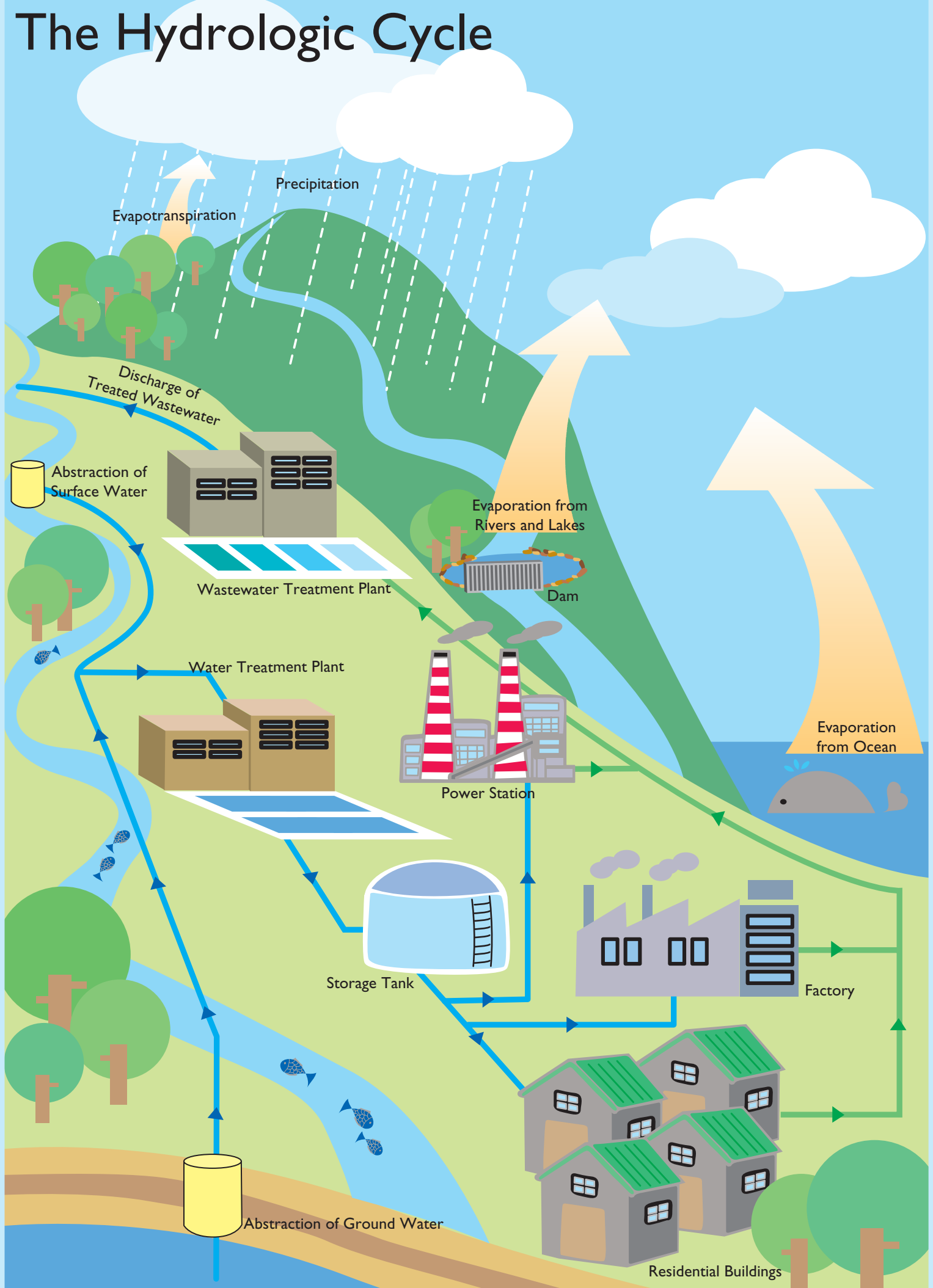


Figure 3.3
Percentage of water loss in the water distribution network
(Source: PMM, MWSC, 2001)

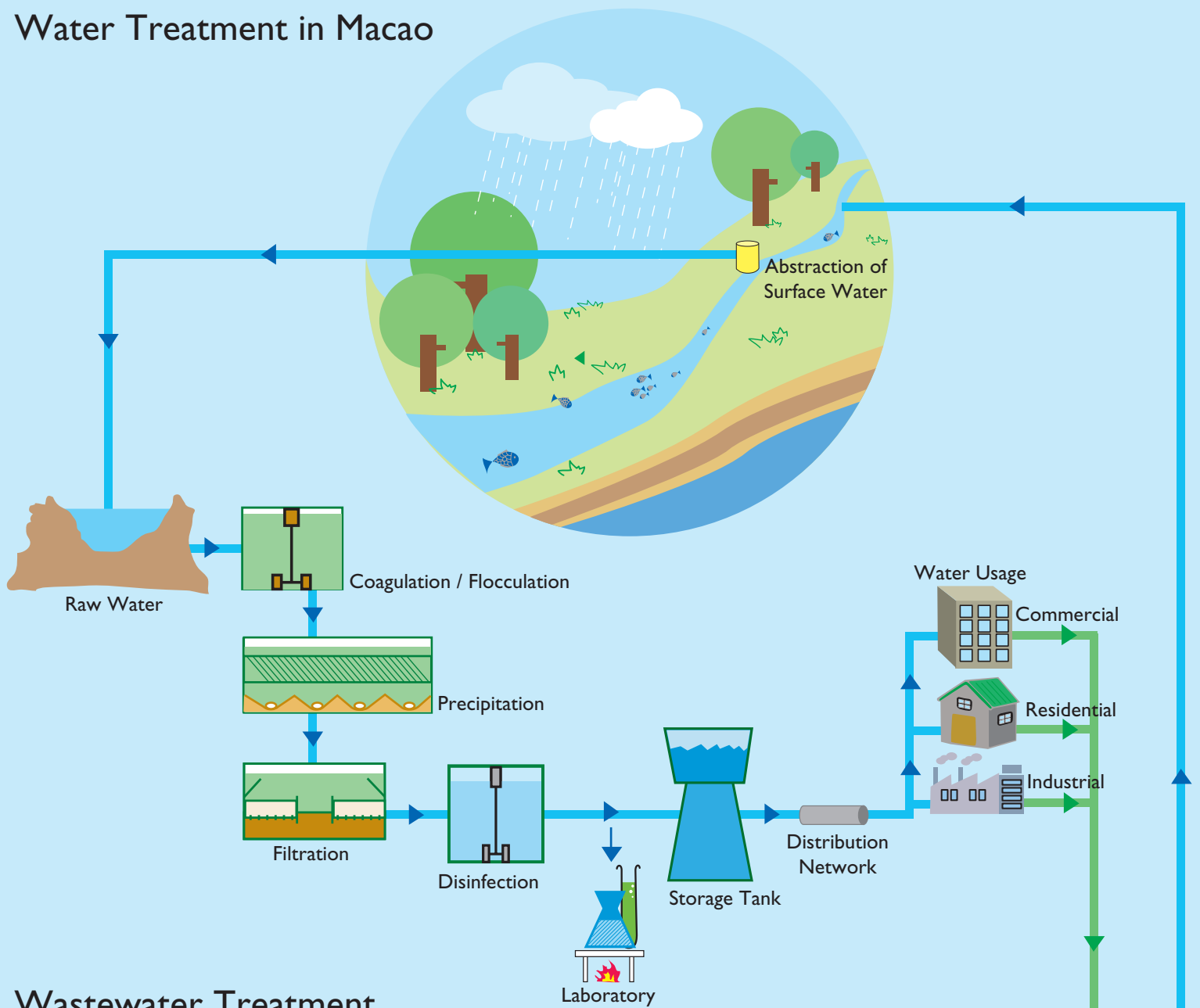
(Note : The data for year 2000 includes the water used by the MWSC workers as well as the backwash water for filtration.)

It is shown that more water is consumed in the Macao Peninsula, but water consumption in Taipa has shown a sharper percentage of increase. This indicates the rapid growth of population in Taipa.

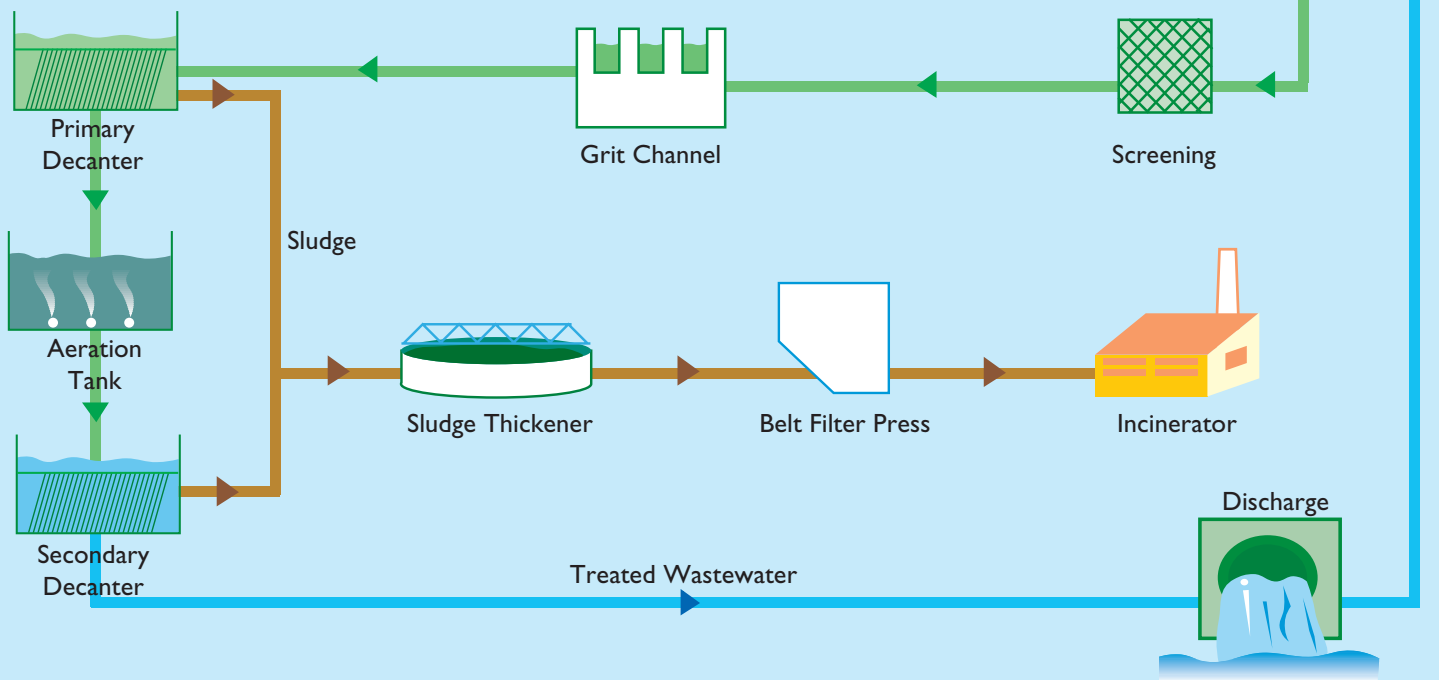
The Hydrologic Cycle



Water Treatment in Macao



Wastewater Treatment in Macao



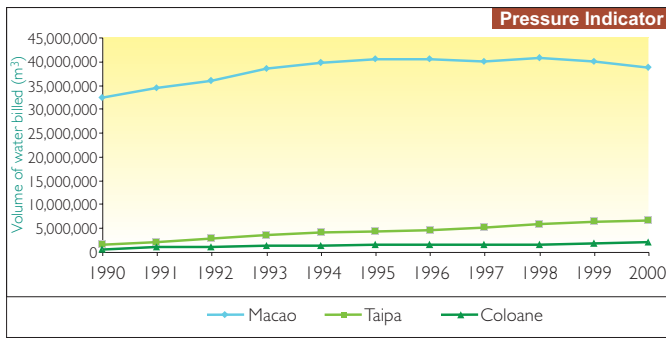


Figure 3.4
Volume of water billed by geographical area
(Source: PMM, 2001)

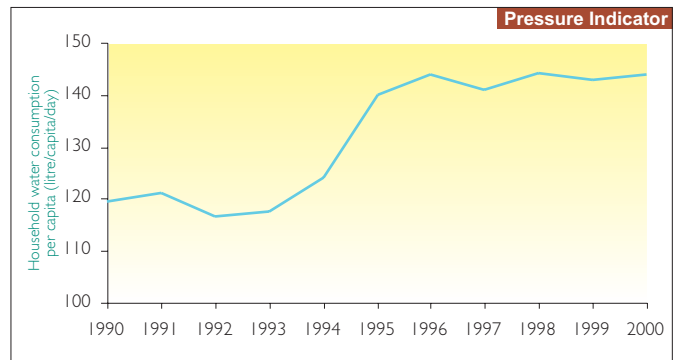


Figure 3.7
Evolution of household water consumption per capita in Macao
(Source: PMM, SCS, 2001)

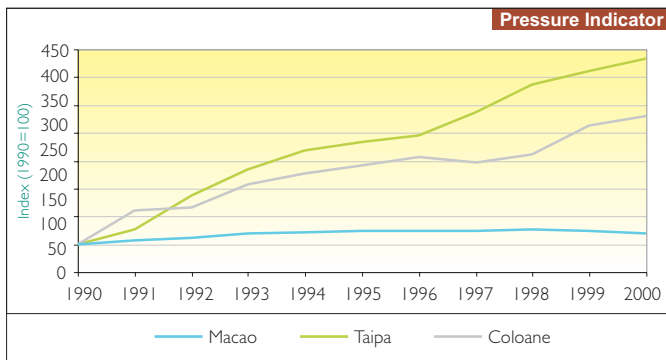


Figure 3.5
Evolution of the water billed volume by geographical area
(Source: PMM, 2001)

Similar to previous years, household is the dominant sector of water consumption in 2000, followed by the commercial sector.

Water consumption by the industrial sector has a significant decrease. Consumption by other sectors has been increasing, especially by the government departments (including PMM, PMI, Incineration Plant and Wastewater Treatment Plants etc.) which shows a 70% increase since 1993.

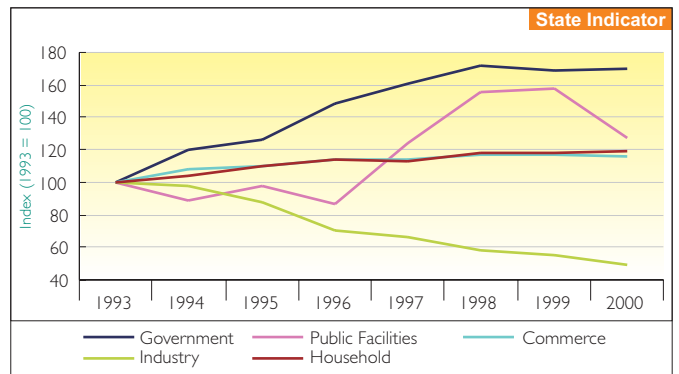


Figure 3.8
Evolution of the water consumption by different sectors since 1993
(Source: MWSC, 2001)

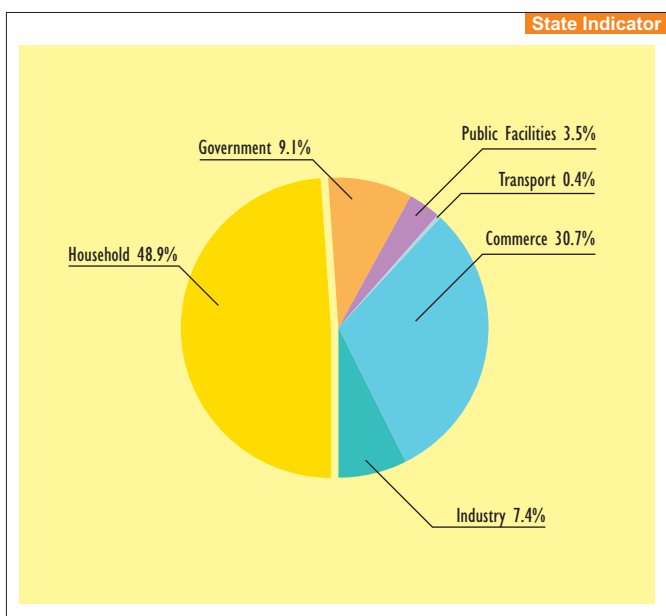


Figure 3.6
Types of water usage distribution in Macao in 2000
(Source: MWSC, 2001)



Household and commerce are the major sectors of water consumption in the Macao Peninsula. As in Taipa, a significant increase in water consumption in both the commerce and household sector, especially in the former. In Coloane, water consumption in the commerce sector has been increasing in the recent years; however, water consumption in the household sector has been decreased.

Water Quality

There are three water treatment plants in Macao. The Ilha Verde Water Treatment Plant yields a total of 120,000 m³ of drinking water per day and supplies water to the Macao Peninsula and part of Taipa. The Outer Harbour Water Treatment Plant has a daily yield of 60,000m³ and supplies water to the Macao Peninsula and part of Taipa. Furthermore, the Coloane Water Treatment Plant yields a total of 10,000 m³ of drinking water per day and supplies water to Coloane and part of Taipa.

The government monitors and controls the local drinking water quality through the Municipal Laboratory of Macao. Raw water samples, treated water samples from the treatment plants and distribution network are being collected in order to conduct bacteriological and physicochemical analysis to ensure that the supplied water quality meets the standards.

The analysis of the raw water quality at Madaomen Canal corresponds to the A2 type, i.e. it requires the normal physical and chemical treatment and disinfection before it can be consumed. The A1 type requires only simple physical treatment and disinfection, while the A3 type requires a sophisticated physical, chemical, filtration and disinfection treatment.

The chloride concentration indicates the degree of water salinity. If it exceeds the standard, it may cause corrosion problems in pipes and adverse effects on human health. In Macao, this parameter will reach values above the desired limits during the dry season. Therefore, dilution of the saline water is necessary and this is a simple and inexpensive method to achieve an acceptable water quality.

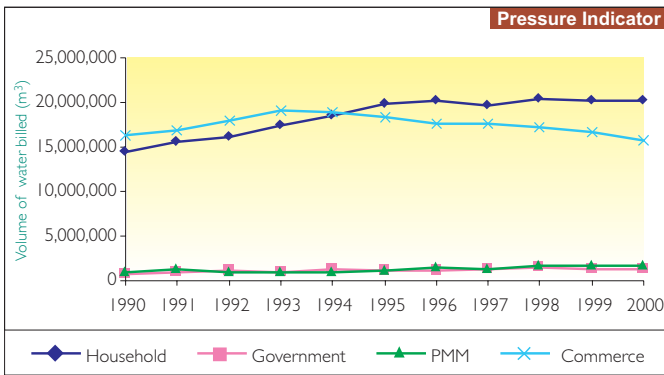


Figure 3.9
Volume of water billed in Macao Peninsula
(Source: PMM, 2001)

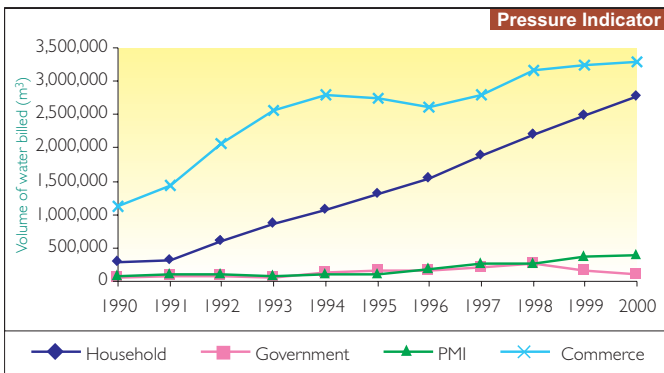


Figure 3.10
Volume of water billed in Taipa
(Source: PMM, 2001)

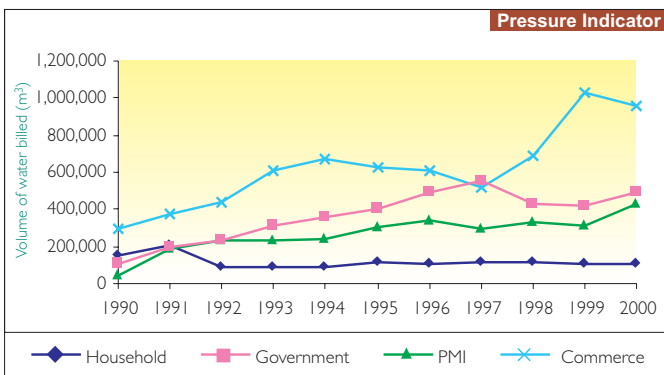


Figure 3.11
Volume of water billed in Coloane
(Source: PMM, 2001)



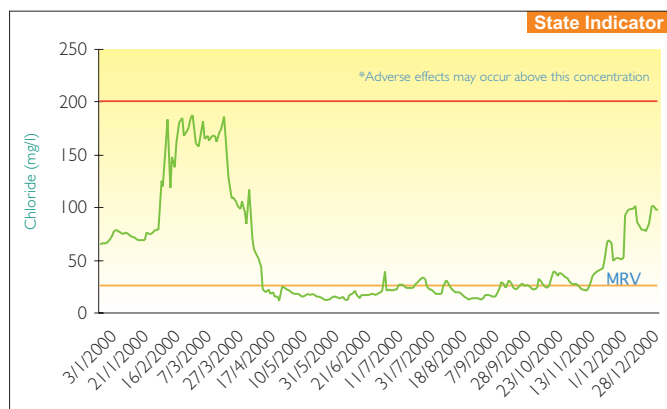


Figure 3.12
Chloride concentration in the Ilha Verde water treatment plant in 2000
(Source: MLM, 2001)

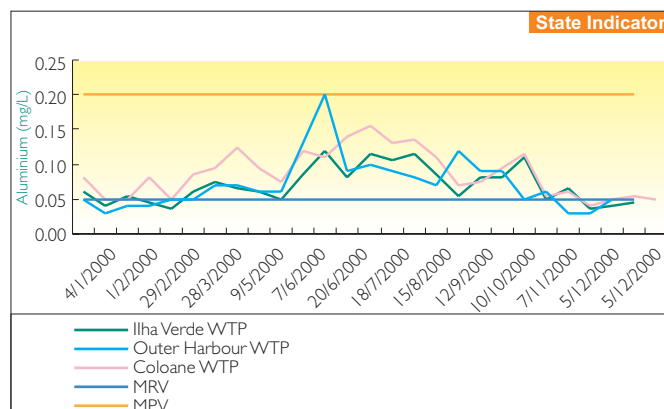


Figure 3.14
Aluminium concentration in the Water Treatment Plants in 2000
(Source: MLM, 2001)

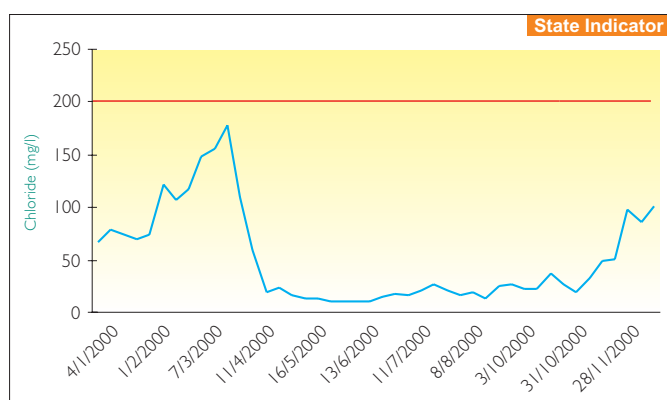


Figure 3.13
Chloride concentration of raw water in 2000
(Source: MLM, 2001)

The mean values of trihalomethane (THM) in 2000 of the Ilha Verde Water Treatment Plant, the Outer Harbour Water Treatment Plant and the Coloane Water Treatment Plant were 53.9 µg/l, 55.3 µg/l and 51.4 µg/l respectively. Although the mean annual value is below the maximum permissible value (MPV) for trihalomethane (100 µg/l), occasional exceedance has occurred. THM is actually comprised of the following four components, chloroform (CHCl₃), dichlorobromomethane (CHCl₂Br), dibromochloromethane (CHClBr₂) and bromoform (CHBr₃). The Municipal Laboratory of Macao started to monitor those four components' level since 1999.

The aluminium (Al) concentration of the treated water has not exceeded the MPV (0.2 mg/l) in 2000. However, when a more stringent recommended standard is concerned, there were respectively 69% and 60% of samples analysed in the Ilha Verde and the Outer Harbour Water Treatment Plant exceeding the Maximum Recommended Value (MRV) (0.05 mg/l) in 2000. A slight decline in exceeding percentages has occurred when comparing to that of 1999, except in the Coloane Water Treatment Plant where 78% of the samples has exceeded the MRV in 2000.

The fluoride concentration is still below the Minimum Permissible Value. Adequate concentrations of fluoride will avoid the development of caries. In the first edition of the Guidelines for Drinking-water Quality by the World Health Organization (WHO) in 1984, a value of 1.5mg/l was established for fluoride. However, there are many factors that affect human fluoride intake including climate conditions and other intake sources. For example, food such as fish and tea are two other possible sources of fluoride intake in Macao.

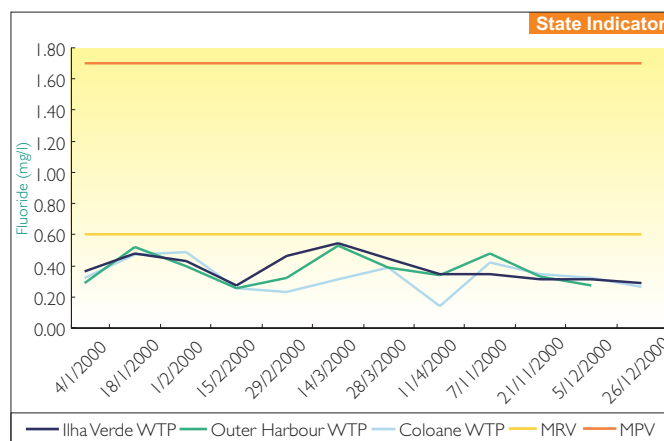


Figure 3.15
Fluoride concentration in the water treatment plants in 2000
(Source: MLM, 2001)

As for violations of **microbiological parameters** in the water distribution network, the situation undergoes a significant improvement in 2000. No violation of total coliform parameter in the water distribution network has been observed.

Unlike previous years, the situation regarding the **total count of bacteria** has also improved. In 2000, there was a large number of violations in the water distribution network of the Macao Peninsula.

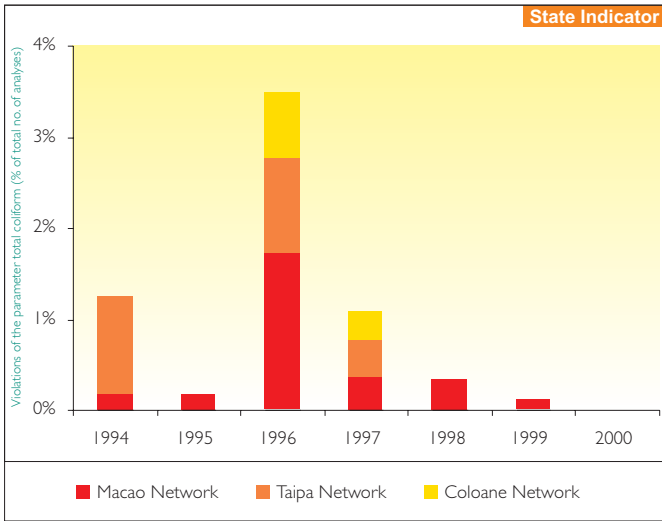


Figure 3.16
Violations of the total coliform parameter in the water distribution network
(Source: PMM, MLM, 2001)

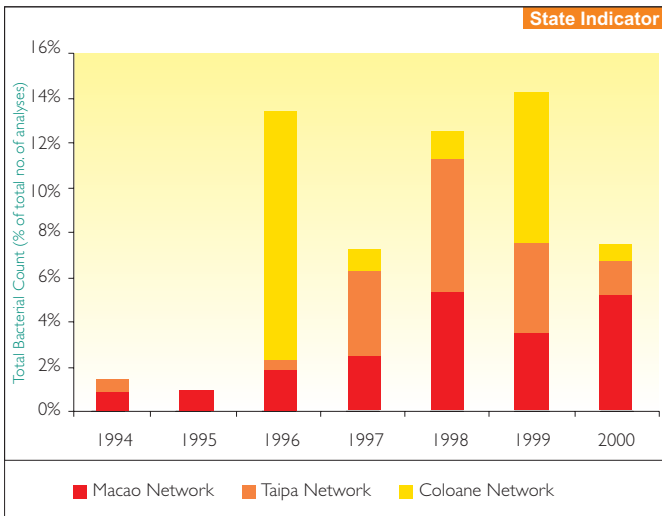


Figure 3.17
Violations of the total bacterial count in the water distribution system
(Source: PMM, MLM, 2001)

When comparing between the volumes of the water treated in 1999 and 2000, there is an increase of 4.67% for the two Macao water treatment plants. Moreover, a rise of 4.8% in the volume of the water introduced into the distribution network is recorded. In 2000, the daily mean water consumption is 129,000 m³.

In the Coloane Water Treatment Plant, there is a 2% increase in the volume of water being treated and an increase of 3.4% in the volume of the water introduced in the Taipa and Coloane water distribution network. In 2000, the daily mean water consumption is 27,000 m³.

In 2000, the peak daily water consumption is recorded to be 180,000 m³. This represents an increase of 4.5%, compared to that of 1998.



3.2 Bathing Beaches and Coastal Water

Coastal Water Quality

Coastal areas have an essential ecological, social and economic value. At the same time, they are vulnerable but unique resource which plays a crucial role in the preservation of the equilibrium of nature. Approximately three fourths of the world population live in coastal areas and so they have to face the inevitable pressure. Fisheries, water transport and tourism share this vital space. It is therefore necessary to build up mechanisms that attempt to harmonise economic development and the preservation of the natural resources of these areas.

Outlying factors are the main coastal water pollution sources of Macao. However, there are also direct discharges into the Estuary from local sources, especially during the rainy season when the combined sewers cannot withstand the loading of both the wastewater and the rainwater. In addition, it is also due to the fact that part of the wastewater sewage system has not been connected to the wastewater treatment plants.

The sampling points of the coastal water monitoring network have been increased from 12 to 13. The new sampling point is located at the coast of Praia do Bom Parto. These sampling points are shown in Figure 3.18 and they have been grouped into 4 zones.

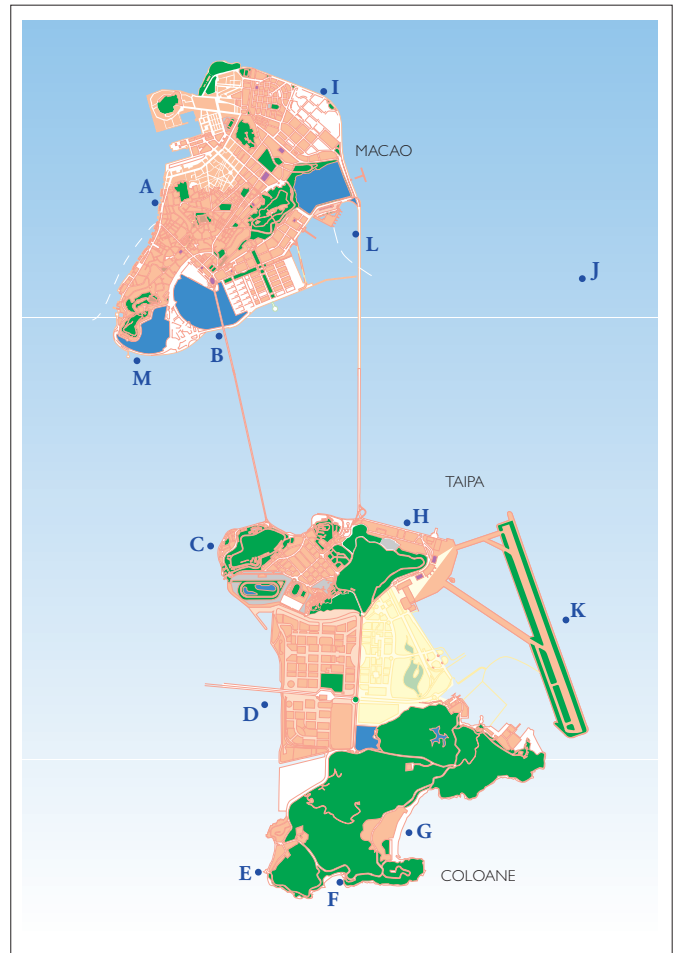


Figure 3.18
Location of sampling points of coastal water monitoring network
(Source: PHL, 2001)

Table 3.1 - Sampling points by zone (Source: HD, 2001)

Zone I	<p>C - Taipa</p> <p>D - Sanitary landfill</p> <p>E - Coloane</p>
Zone II	<p>F - Cheoc Van</p> <p>G - Hác Sá</p> <p>K - Airport</p> <p>J - Reference point</p>
Zone III	<p>H - Pac On</p> <p>L - Outer Harbour</p> <p>I - Areia Preta</p>
Zone IV	<p>A - Inner Harbour</p> <p>B - Praia Grande</p> <p>M - Praia do Bom Parto</p>



During the year 2000, the Health Department (HD), the department responsible for the monitoring of coastal water quality, has introduced a new index system for the assessment of coastal water quality. In order to get a comprehensive overview of the evolution of the water quality, calculations as from 1991 have been carried out.

Pollution Index

The calculation of the **Pollution Index (I)** is based on a numerical average of the coastal water quality data (refer to SoER 2000), and thereon categorizes into the following classes:

- Class 1: $I < 0.50$clean and unpolluted water;
- Class 2: $0.50 < I < 0.75$...water with acceptable quality;
- Class 3: $0.75 < I < 1.00$...polluted water that affect the normal growth of plants and organisms;
- Class 4: $I > 1.00$polluted water that causes adverse effects on public health.

With the application of this index to Macao, it is concluded that Zone II has an acceptable quality because it satisfies with the criteria of Class 2 water. However, it should be noted that the index of Hác Sá and Cheoc Van, both are famous recreational areas, is approaching the Class 3 water quality.

The index of the Outer Harbour and Areia Preta (Zone III) has already reached Class 4. The whole Zone IV is seriously polluted and the pollution index has been increasing since 1996.

To conclude, by analysing the pollution index, the situation of coastal water pollution is getting worse in Macao and some sampling points have even reached critical values.

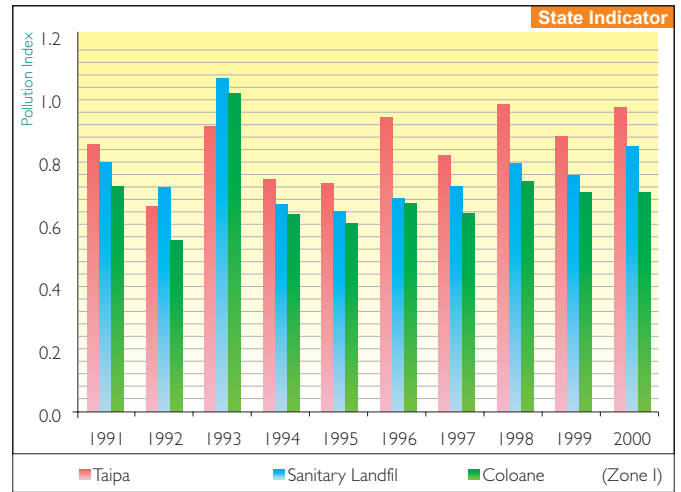


Figure 3.20
Pollution index in Taipa, Sanitary Landfill and Coloane from 1991 to 2000
(Source: HB, 2001)

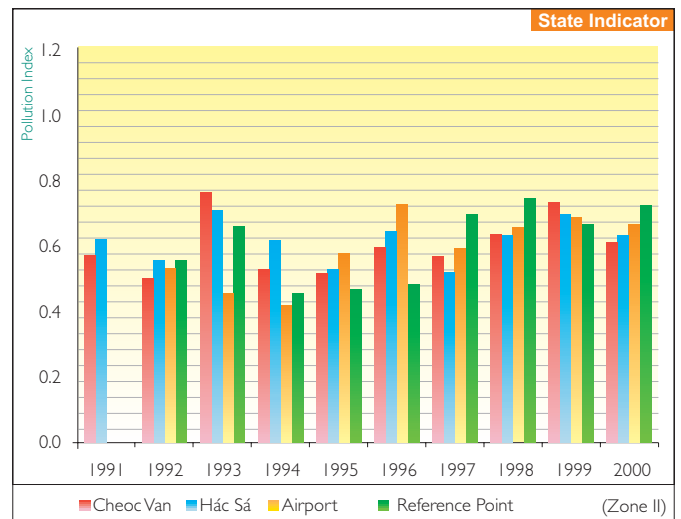


Figure 3.21
Pollution index in Cheoc Van, Hác Sá, Airport and Reference Point from 1991 to 2000
(Source: HB, 2001)

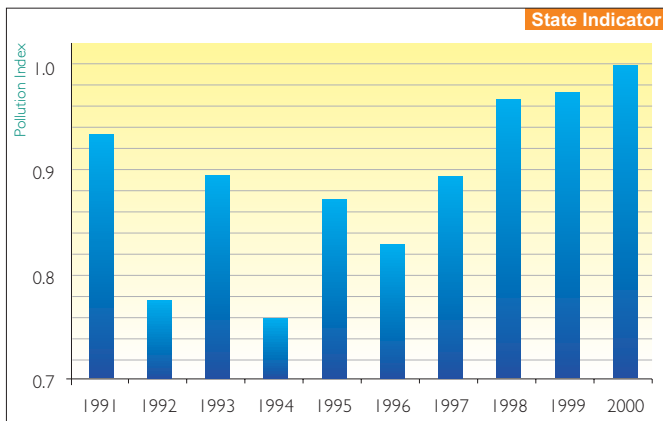


Figure 3.19
Coastal water pollution index of Macao from 1991 to 2000
(Source: HB, 2001)



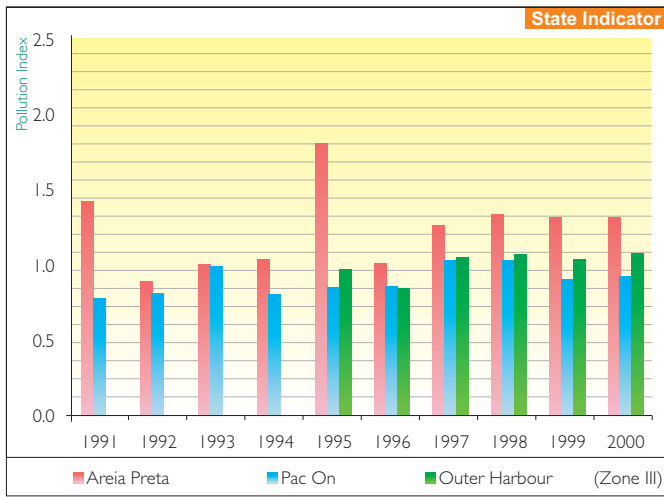


Figure 3.22
Pollution index in the Outer Harbour, Pac On and Areia Preta from 1991 to 2000
(Source: HB, 2001)

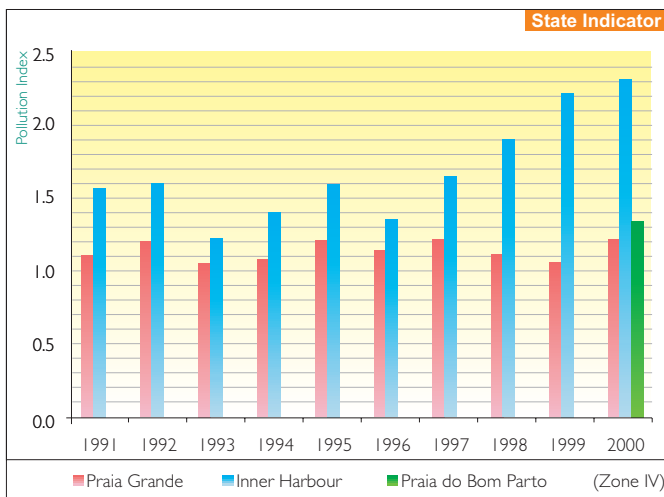


Figure 3.23
Pollution index in the Inner Harbour, Praia Grande and Praia do Bom Parto from 1991 to 2000
(Source: HB, 2001)

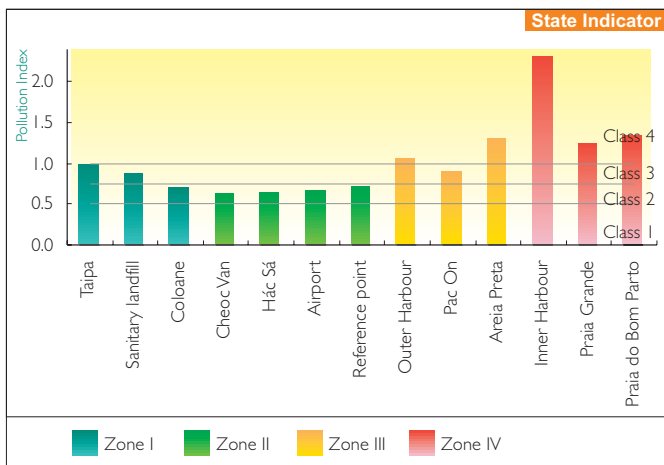


Figure 3.24
Pollution index allocated to each sampling point in 2000
(Source: HB, 2001)

Nutrient Index

In addition, a **Nutrient Index (E)** has also been introduced, which is based on the analysis of BOD, phosphorous and inorganic nitrogen. The need for studying this index arises from the increasing number of red tide in the Pearl River Estuary. When red tide occurs, the colour of the water will turn into brownish red or dark green because of the rapid growth of certain algae. The growth rate of this type of algae is determined by factors such as sunlight, aquatic nutrients, trace elements, water temperature, currents and salinity. Their growth and accumulation cause the decrease of dissolved oxygen level and the release of toxic substances into water. As a consequence, with a deteriorating water environment, more fish will be killed.

$E > 1$ means that the concentration of nutrients in water is extremely high. From Figures 3.25 and 3.26, it can be seen that the sampling points of Areia Preta, Praia do Bom Parto and the Inner Harbour are the most serious areas, where the index has already exceeded 80. With the operation of the Macao Wastewater Treatment Plant in 1995, there was a decrease in the nutrient index. However, with the growth of population, the nutrient index rises again.

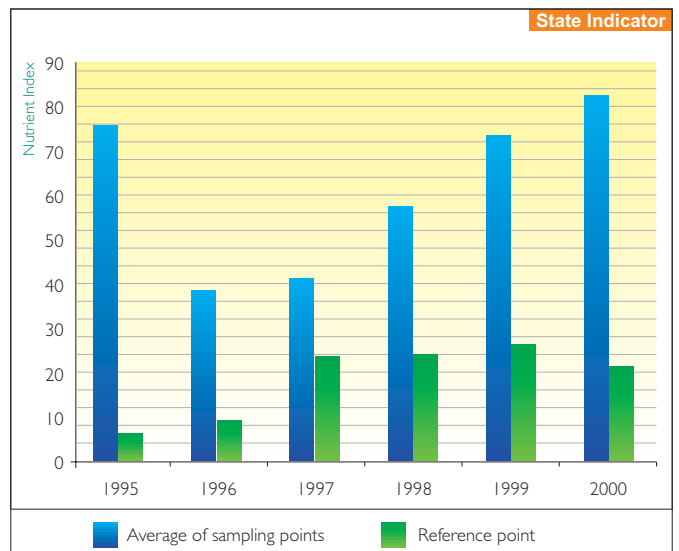


Figure 3.25
Annual variation of the nutrient index from 1995 to 2000
(Source: HB, 2001)

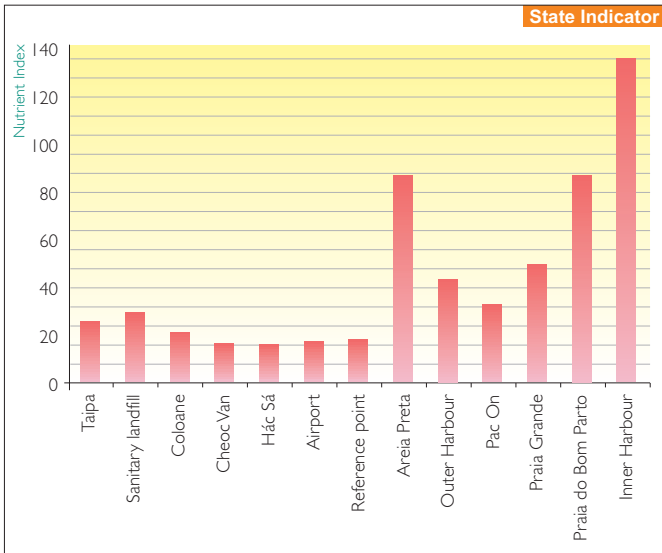


Figure 3.26
Nutrient index in each sampling point in 2000
(Source: HB, 2001)

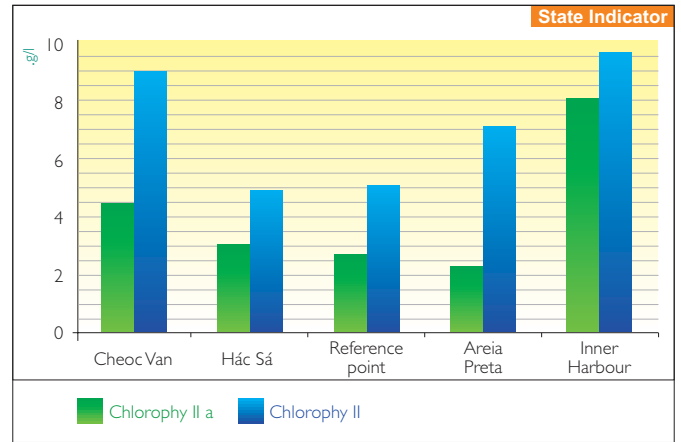


Figure 3.27
Chlorophyll and chlorophyll a concentration in 2000
(Source: HB, 2001)

Chlorophyll and Chlorophyll a

It is worthwhile to mention that chlorophyll and chlorophyll a are indicators for algae growth, commonly used in the Pearl River Estuary. Analysis shows that the chlorophyll concentration at Cheoc Van and Inner Harbour is comparatively higher, owing to the presence of large amounts of water hyacinths in the water. The mass reproduction of water hyacinths forms a thick layer covering the water surface, hindering the navigation course and lowering the dissolved oxygen level that leads to the death of aquatic organisms.

Heavy Metals

Heavy metals such as arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb) and other compounds are toxic and dangerous to human health and the water body since they can accumulate in the organic body. During 2000, the number of sampling points analysing the above parameters have increased, including Praia Grande (B), Cheoc Van (F), Hác Sá and Outer Harbour (L). Analysis indicates that the heavy metal concentrations have not caused serious marine environmental pollution.

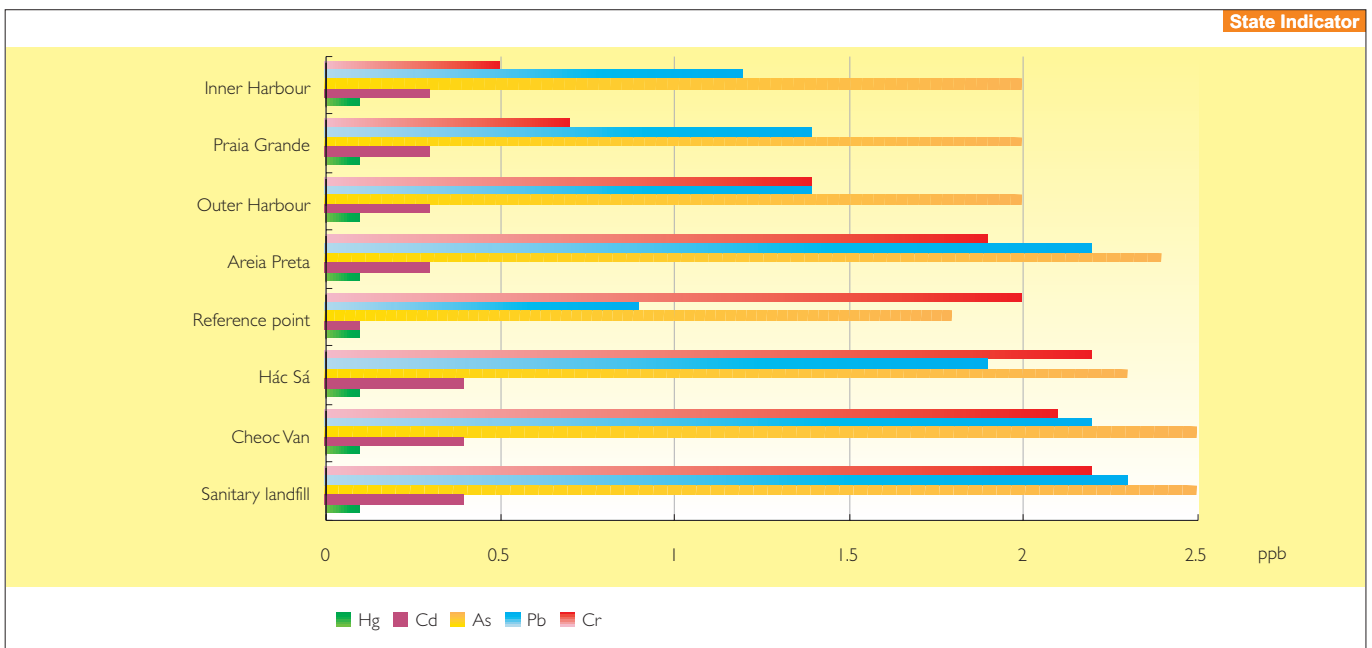


Figure 3.28
Annual mean of the heavy metals concentration in 2000
(Source: HB, 2001)

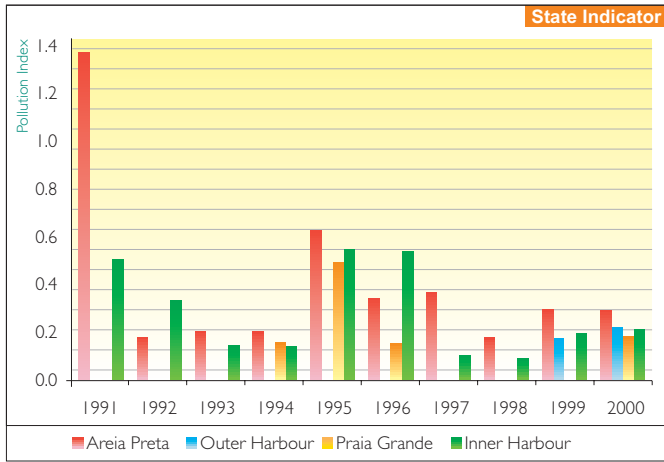


Figure 3.29
Heavy metals pollution index in Macao from 1991 to 2000
(Source: HB, 2001)

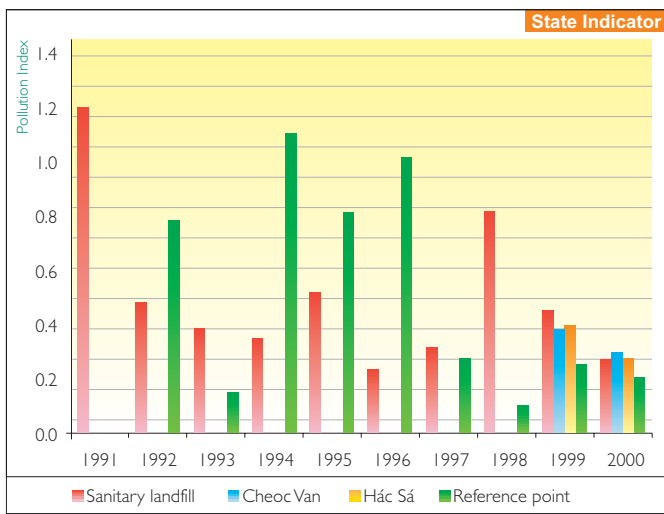


Figure 3.30
Heavy metals pollution index on the Islands from 1991 to 2000
(Source: HB, 2001)

Dredging

The settling of sedimentary solids causes a series of problems in the Pearl River Delta, in particular the elevation of riverbeds, the obstruction of water ways and estuarine expansion.

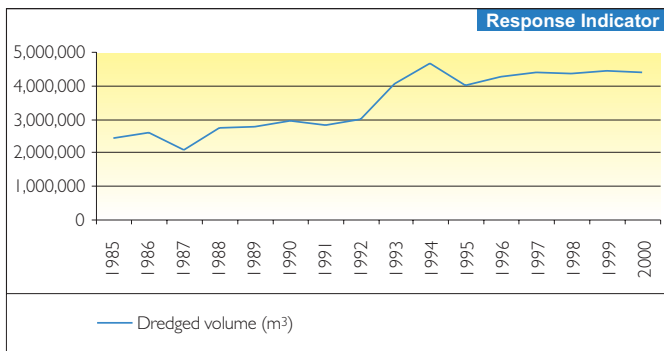


Figure 3.31
Dredged volume
(Source: PA, 2001)

Therefore, it becomes necessary to dredge several million cubic meters of sediments per year.

As stated before, the coastal water quality of Macao not only depends on local pollution sources but also the pollutions from the Pearl River Delta.

The extent of eutrophication and the increase of algae each year are caused by the high concentration of nitrogen and phosphorous. The sediments increase the turbidity concentration in the water body. Thus, high turbidity together with low salinity are still the two main characteristics of the coastal water quality of Macao.

The sampling point with the highest pollution index is the Inner Harbour and the index has been reaching a level to be worried.

Therefore, it is necessary to collaborate with the relevant authorities in the nearby regions and research on methods to solve environmental problems and control the pollution sources.

Bathing Water Quality

Beaches

The monitoring of water quality in the Cheoc Van and Hác Sá beaches is the responsibility of the Public Health Laboratory (PHL). From April to October in 2000, the sampling frequency is twice per week at two locations of each beach (another sample is taken within the same week whenever the microbiological values are exceeding the standards).

Microbiological and physicochemical parameters are analysed and, whenever possible, the results are compared with the



legislated limit values of China, Hong Kong and the European Union.

At present, *Escherichia coli* is the only indicator being analysed to distinguish whether the water body is microbiologically polluted. When analysing the evolution of the situation and comparing the values with those regulated for Hong Kong, where the geometric mean of the measured values should be below 180 CFU/100 ml, it may be concluded that the concentration of *Escherichia coli* in the beaches of Macao has increased. It is gradually deviating from the limit for acceptable quality.

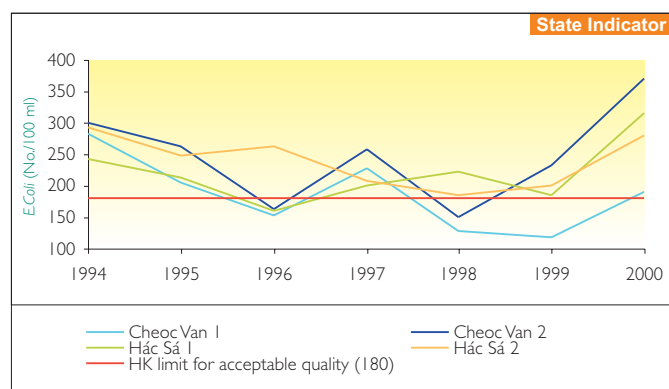


Figure 3.32
Geometric mean of *E. coli* annual values
(Source: PHL, 2001)

During 2000, the cholera virus (*Vibrio cholerae*) was absent in the beaches, in contrary to the situation in 1999.

As for the analysis of physicochemical parameters, it should be noted that the oxidability of some samples are above the guideline values of the PRC standard for bathing water (GB3097-82).

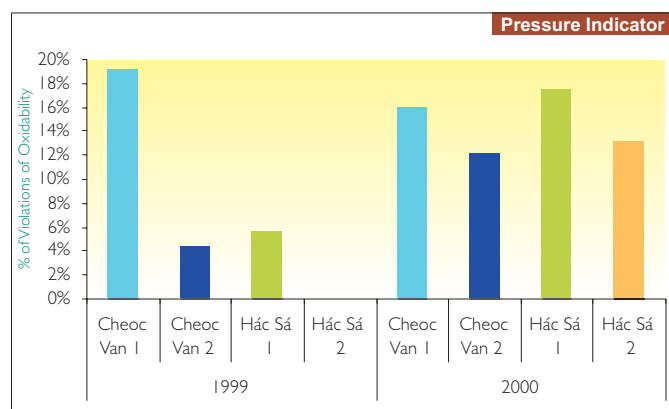


Figure 3.33
Percentage of violations of oxidability
(Source: PHL, 2001)

Coastal Erosion

In September and October of 2000, the condition of sand erosion in the Hác Sá and Cheoc Van beaches has reached a high level when compared to the situation of previous years. The loss of sand has resulted in part of the banks, paths and trees to collapse, affecting the beach environment.

Although the beaches are considered to be a dynamically equilibrium system, i.e. the removal of sand and its accumulation in the coast is a natural periodic phenomenon. However, the accumulation of sand, which is supposed to occur during the wintertime, is not enough to compensate the loss in 2000.

This type of coastal erosion may be the result of a number of natural factors, like wind, waves, currents, and storms etc. In addition, it is also due to human activities such as the reclamation of land from sea, dredging, mining and building of coastal slopes.

Thus, the Port Authority has already started a monitoring programme to collect regularly the information about the amount of sand loss. This programme aims at investigating the driving factors of erosion and finding appropriate measures.



3.3 Wastewater Management

There are three wastewater treatment plants (WWTP) in the Macao Special Administrative Region, situated at the peninsula and the islands in order to solve the environmental problems caused by polluted water.

Till the end of 2000, there are still drainage of some areas in Macao not connected to the WWTP and misconnection of sewage pipes to the storm water pipes. These cause coastal water pollution and thus by increasing the inspection work can minimize the adverse effects to the public health.

In 2000, it was estimated that about 1,800,000m³ of wastewater was directly discharged into the water body due to the overloading of the influent volume to the WWTP during peak hours. In order to solve this problem, the WWTP in Macao is building a storage tank with a capacity of 10,000m³ to relieve the pressure during peak hours. The storage tank is expected to be in operation in 2002.

A rising evolution of the volumes treated in the Macao Wastewater Treatment Plant is in fact mainly due to the growing number of residents connected to the drainage system, in contrary to the situation of the Taipa Wastewater Treatment Plant. Since only part of the drainage system is still combined in Taipa, there is little correlation between the volumes and the annual mean precipitation in the past few years.

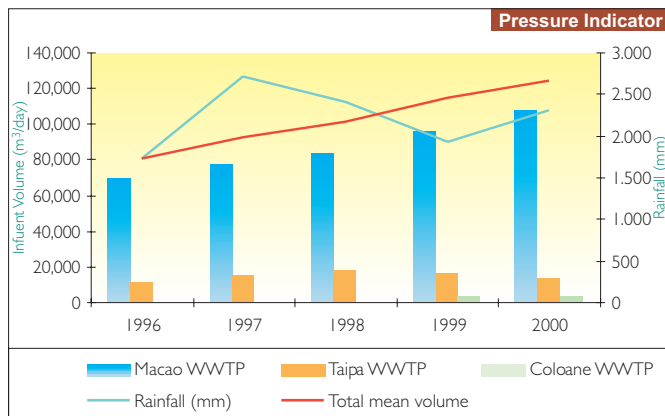


Figure 3.34
Daily mean influent volume in the WWTPs
(Source: OI.D, 2001)

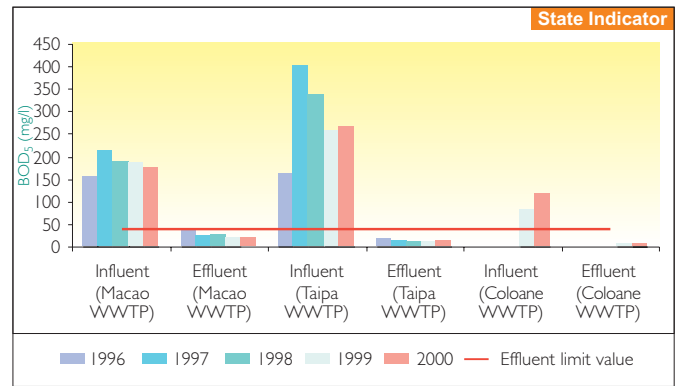


Figure 3.35
Evolution of biochemical oxygen demand (BOD₅) in the influent and effluent volumes in the WWTPs
(Source: OI.D, 2001)

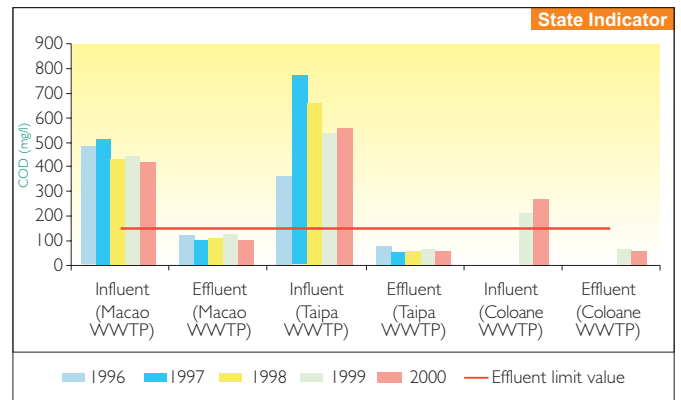


Figure 3.36
Evolution of chemical oxygen demand (COD) in the influent and effluent volumes in the WWTPs
(Source: OI.D, 2001)

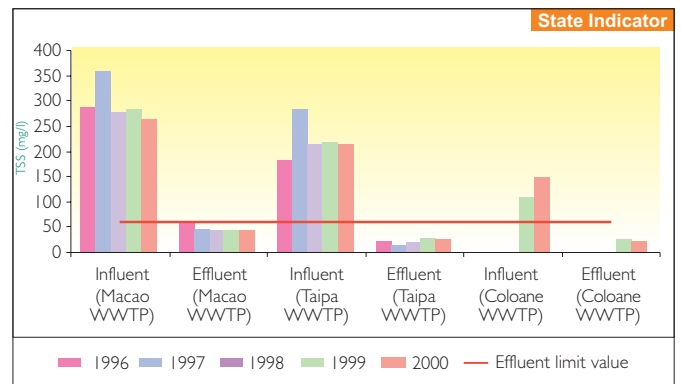


Figure 3.37
Evolution of total suspended solids (TSS) in the influent and effluent volumes in the WWTPs
(Source: OI.D, 2001)



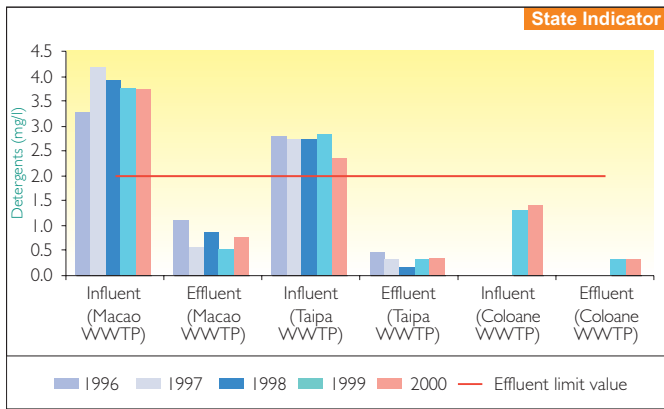


Figure 3.38
Evolution of detergents in the influent and effluent volumes in the WWTPs
(Source: OI.D, 2001)

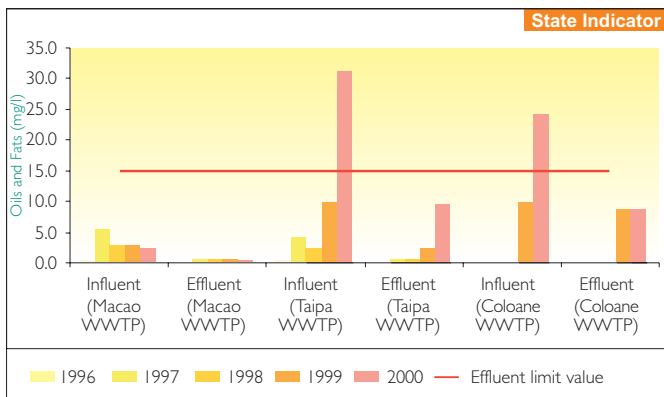


Figure 3.39
Evolution of oils and fats in the influent and effluent volumes in the WWTPs
(Source: OI.D, 2001)

The laboratory of the WWTPs is responsible for monitoring the effluent quality to make sure that it is within the limit when being discharged to the Pearl River Estuary.

It is shown from the effluent quality of each WWTP that the limiting values have not been exceeded. Thus, the effluent from the WWTPs has not been causing pollution problems to the Pearl River Estuary.

The Macao SAR government has planned to have a project in monitoring the effluent quality of the storm water as well as that of the wastewater. The parameters to be analysed include:

- Ammonia
- Chlorides
- Fecal coliform
- Conductivity
- Colour
- *E. Coli*
- Total phosphorous
- Nitrates
- Nitrites
- Oxidability
- Dissolved oxygen
- pH
- Total suspended solids
- Turbidity



4. Waste

4.1 Waste Generation and Management

The worldwide rapid economic growth and the changes in people's consumption pattern have been closely related to the increase of waste generation. However, the percentage of waste reclamation (recycling, recovery and reuse) is not yet sufficient to offset the increasing trend of waste generation.

Some of the environmental pressures resulting from the increase of waste generation are the loss of resources and energy. The environmental impacts caused by the collection, treatment and final disposal of waste include the taking up of landfill space, water and air pollution and the emission of greenhouse gases. In order to minimise such impacts, it is necessary not only to reduce waste generation but also to promote waste reclamation.

The major sources of urban waste come from households, commerce and services (shops, hotels and offices), industries and health services (hospitals and health care facilities).

Since 1993, there has been an increase of 45% in the amount of waste generation in Macao. However, the population has been growing at a much slower rate and this implies that each inhabitant is generating an ever-growing quantity of waste. As far as the GDP is concerned, a decrease was recorded in Macao from 1997 to 1999 due to the Asian economic crisis. In 2000, however, there is an increase in the GDP again due to the hand-over, inducing a boost of about 23% in the number of visitors, which has brought more wealth to the economy.



In 2000, the amount of waste (domestic, commercial and industrial) collected by the Waste Service Company (WSC) reached 229,444 tonnes. This corresponds to 1.44 kg/inhabitant/day of waste produced.

The total amount of solid waste incinerated daily in the Macao Incineration Plant (MIP) has been growing annually. Comparing to 1999, there has been an increase of 2.3% in 2000. In spite of this increase, the total amount of waste incinerated per day has not yet reached the maximum daily capacity (864 tonnes) of the MIP.

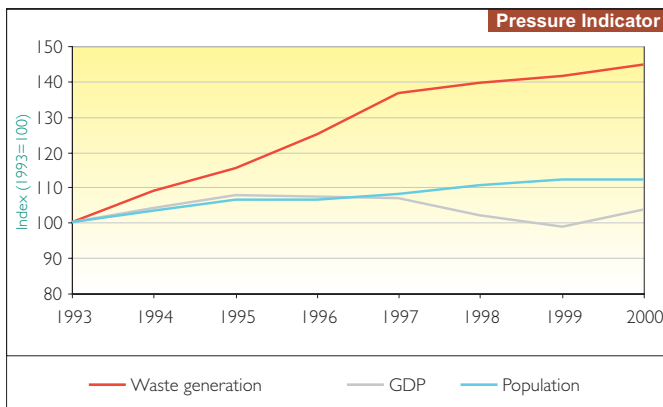


Figure 4.1
Evolution of the waste situation in Macao
(Source: SCS, OI.D, 2001)

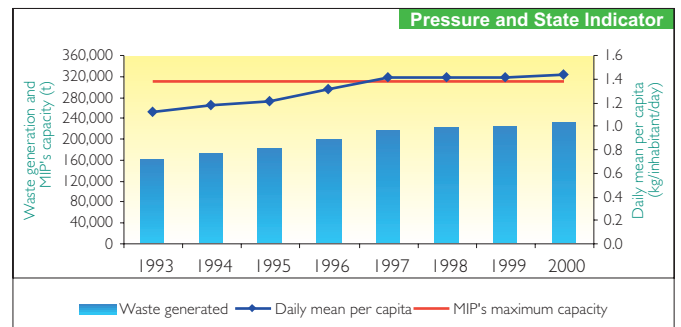


Figure 4.2
Evolution of waste generation and daily mean per capita
(Source: OI.D, 2001)

The department responsible for the removal of waste from the sea is the Port Authority (PA). This authority has been promoting cleaning operations of coastal areas, particularly in removing solid waste and hydrocarbons that are causing marine pollution. Solid waste found at sea is essentially some domestic waste from ships docked at riparian zones and piers (wood pallets, plastic bags, packaging materials), and of water vegetation (water hyacinths).

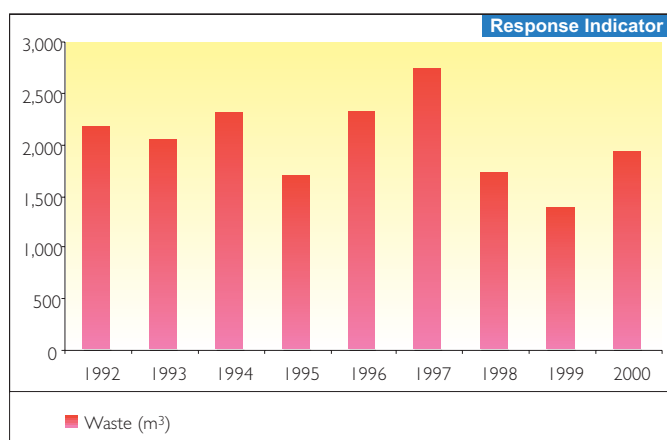


Figure 4.3
Evolution of the amount of waste removed from the sea
(Source: PA, 2001)

Domestic waste is being delivered to the Incineration Plant for treatment. Regarding the waste source, physical and chemical composition, no up-dated information has been available since the previous reports. Therefore, renewed information would be very useful, since it would reveal the population's consumption pattern and could act as a guideline for the future policy on waste management. By identifying the waste source, the most suitable and implemental facilities on prevention, reuse or reclamation of waste measures can then be determined.

Besides the collection of waste, the WSC is also responsible for the placement and maintenance of public waste containers. By 2000, all these waste containers had been replaced by those with pedals.

Regarding the evolution of the amount of incineration residue and fly ash (by-products from incineration and the treatment of waste), there has not been any significant change since 1995. It shows a tendency for a slight increase, which is brought about by the increase on the amount of incinerated waste.

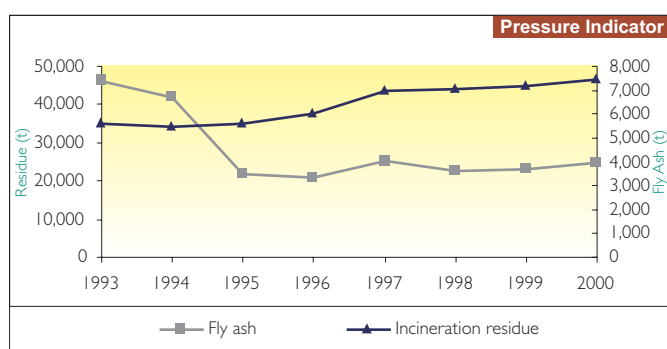


Figure 4.4
Incineration residue and fly ash generated in the MIP
(Source: OJD, 2001)

The quantity of recovered ferrous metals is also steady. Waste not suitable for incineration or with low calorific power (e.g. air conditioners, refrigerators and construction waste etc.) will be sent directly to the landfill for disposal. The amount of this type of waste shows a decline last year:

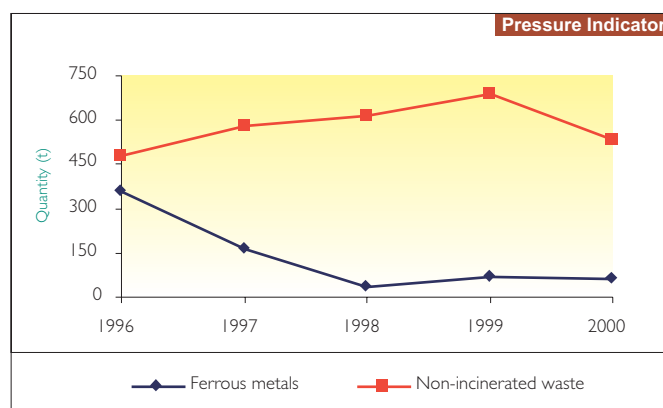


Figure 4.5
Recovered ferrous metals and non-incinerated waste
(Source: OJD, 2001)

The combustion gases emitted by the Incineration Plant are continuously monitored to make sure that they are not exceeding the maximum permissible values of adopted standards. It is worthwhile to note that up to this moment, the parameters analysed (HCl, SO₂, HF and particulates) have never exceeded the established limits.

Research on the monitoring of other pollutants generated during the incineration process such as heavy metals, dioxins and furans should also be carried out since the contact of these pollutants with human beings may cause serious health effects, either through inhalation, ingestion or dermal contact.

The amount of waste generated by the Macao Electric Company (MEC) has been declining both in the Macao Plant and in the Coloane Plant. However, the case is not true for Hovione and the amount of waste has been increasing.

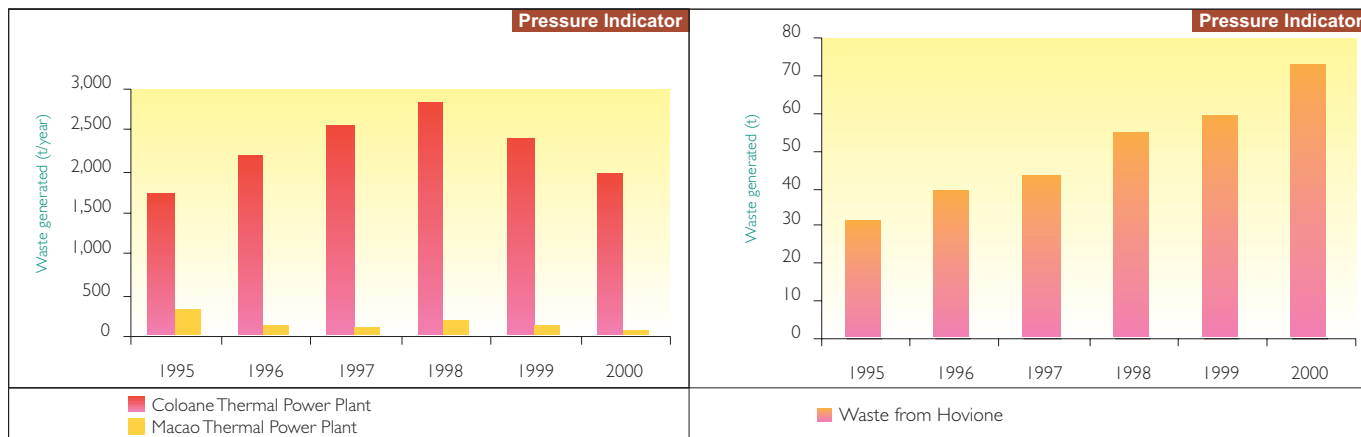


Figure 4.6
Waste generation in the MEC and Hovione
(Source: MEC and Hovione, 2001)

The final disposal of waste is still being delivered to the Seac Pai Van Landfill in Coloane. This landfill is divided into three distinct areas, where mainly three different types of waste are disposed: incineration residue and fly ash from the MIP, construction and demolition waste from civil construction, and dead animal bodies (horses corpse from the Jockey Club and others).

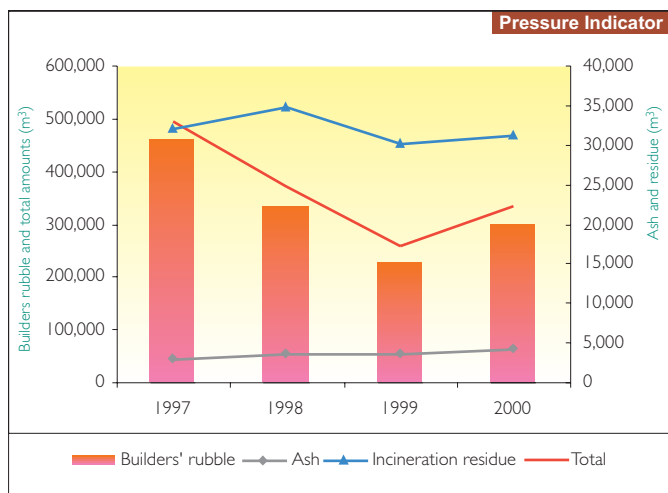


Figure 4.7
Volume of waste disposed into the landfill
(Source: PMM, 2001)

The volume of construction and demolition waste disposed into the landfill has been increasing, different to what has been happening in previous years.

Fly ash is the by-product of treating combustible gases (HCl, HF, SO₂ and NO_x) during the incineration process. Since it may contain substances harmful to the public health and the environment, it can be considered as hazardous waste. According to the information provided by PMM, the Municipal Laboratory of Macao will conduct routine analysis on the fly ash content to make sure that these harmful substances are danger free.

Fly ash is collected in impervious containers, which is carried from the Incineration Plant to the landfill after having been filled up. It will be disposed into specific landfill cells designed for fly ash and industrial waste, which are distributed with impermeable liners.

After each cell is completely filled, it will be covered by a layer of earth, then another layer of impermeable liner and finally another layer of earth, on which small-sized plant species (e.g. grass) are planted. Whenever there is rainfall during the landfill process, the water accumulated inside the cell will be pumped, collected into a pipe and then treated in the Coloane Wastewater Treatment Plant.

It is worthwhile to mention that the dead animal bodies are subject to a sanitary inspection prior to disposal into specific cells of the landfill. These specific cells, which are located about 500 meters away from the coastal area, are not distributed with impermeable liners so as to provide a good permeability



conditions for rapid decomposition. In a short or mid-term period, this procedure should be subject to a reappraisal.

Due to the fact that this landfill is reaching its limiting capacity, it is necessary to locate a new sanitary landfill and the feasibility study has been concluded. This new sanitary landfill will be situated to the West of the International Airport of Macao. The first phase of construction will occupy an area of 18,000 m² and this will have a three-year disposal capacity with possible room for expansion. Three disposal areas will be allocated for the following three types of waste:

- Incineration residue from the MIP, construction waste and other materials resulting from excavations;
- Waste that has high organic content and can be degradable in the course of time;
- High polluting waste such as the fly ash from the MIP.

The leachate collected from the cells will be subject to chemical precipitation pre-treatment prior to discharge. Moreover, there will be a vegetation barrier consisting of tall trees surrounding the sanitary landfill to minimize the visual impact.



4.2 Domestic Consumption

Household and government consumption is a very important indicator of sustainable development at economic, social and achieve environmental level. It is desirable to meet the basic needs and achieve a better quality of life, having minimum possible impact on natural resources and succeed in the minimization of waste and pollutants emissions - a process known as "Dematerialization of the economy".

Reality indicates that the per capita waste generation in Macao has been rising more or less gradually. This shows that each citizen consumes an ever-increasing quantity of products.

Energy consumption is affected by the industrial and transport sectors, as well as by energy policy and prices. It plays a fundamental role on the daily life of citizens, due to the fact that a substantial part of the activities depend on energy. A decline on energy consumption has been recorded since 1997, as far as the household sector is concerned. An increase on household water consumption has been occurring over the years and this has to do with the population growth as well as with an increase in the mean daily household consumption per capita. (see Water Abstraction)

It can, therefore, be concluded that, as far as domestic consumptions are concerned, there is still things that could be done for the sustainable development of Macao. The user-pays and the polluter-pays principles will be two good examples of important instruments to achieve the above goal.

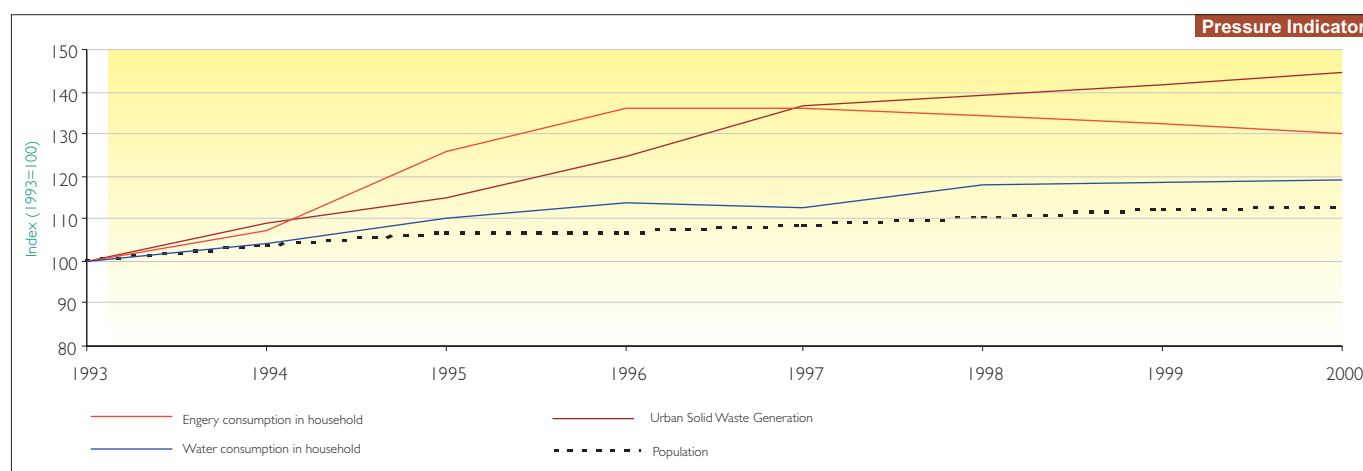


Figure 4.8
Analysis of household consumptions
(Source: SCS, OID, 2001)

5. Natural Conservation

Biological diversity plays a crucial role among human beings since around 40% of the world's economy and 80% of peoples' need depend on biological resources.

The numbers and varieties of organic organisms are evolved from living creatures on Earth. Biodiversity depends on a complex relationship among factors such as the diversity of habitats, the multiple aspects of human activities, soil and climate conditions and the variability of topography.

Human activities such as the development of agriculture, fishery, industry, transport and urbanization, together with the natural evolution process, are the main reasons for the distinction of species. The fact that the ecosystems and species are subject to increasing threats, leading to a significant decline of biodiversity. This trend may have wide-ranging implications in the economic and social development of the human community, which will cause profound environmental changes in the medium and long term.

Therefore, it is necessary to keep the protection of the natural environment in pace with economical development.

Although Macao has a geographical area of approximately 25km² and a high population density, many projects have been developed with the objective of creating green spaces. Among all, Coloane is the most important green area with Seac Pai Van Park being set up for the preservation of rare flora species and the improvement of local vegetation diversity.

In addition, it is necessary to pay attention and conduct research on new ecological invasion problems such as *Mei Gem Gug* (*Mikania micrantha*) and reinforce coastal environment protection.



5.1 Green Spaces

In 2000, the area of Macao has increased by 0.7 km², mainly due to the reclamation works on the Praia Grande Lake. The area of green spaces has also increased to 5,018,619 m², of which 637,307 m² is located in the Macao Peninsula, 509,637 m² in Taipa and 3,871,675 m² in Coloane. Comparing to 1999, the area of green spaces has expanded by 2.3% and the green spaces per capita has increased to 11.5 m².

However, due to the increase in the total geographical area of Macao, the percentage of green spaces has decreased slightly from 20.6% to 19.8%.

The number of trees planted along the streets and safety islands of the Macao Peninsula is 5,424 (a 2.5% increase compared to 1999) and the number of trees in the reforested zones of the Islands is 417,500 (a 1.3% increase compared to 1999).

On the Macao Peninsula, the increase of green spaces is particularly due to the construction of new recreational areas, playgrounds, safety islands and street lawns; while in Taipa and Coloane, the increase is mainly from the new green spaces in road dividers and roundabouts.



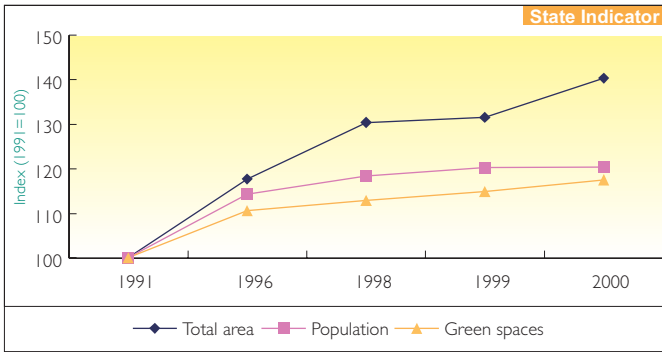


Figure 5.1
Evolution of total area, population and green spaces
(Source: PMM, PMI, SCS, 2001)

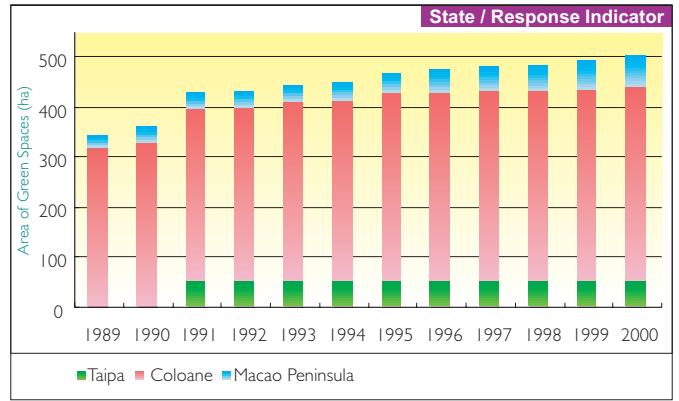


Figure 5.5
Area of green spaces in Macao
(Source: PMM, PMI, SCS, 2001)

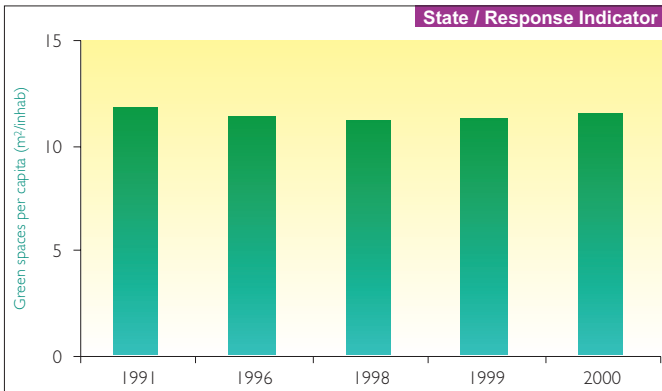


Figure 5.2
Area of green spaces per capita
(Source: PMM, PMI, SCS, 2001)

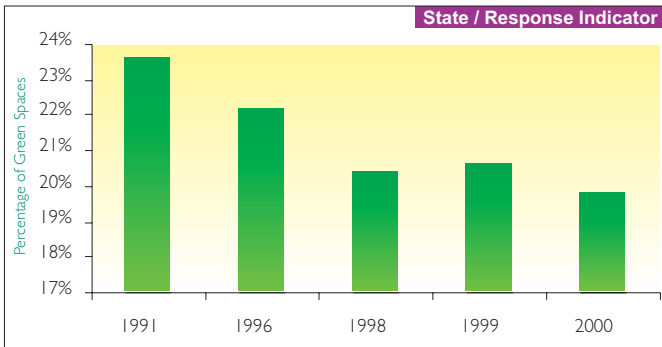


Figure 5.3
Percentage of overall area covered by green spaces
(Source: PMM, PMI, SCS, 2001)

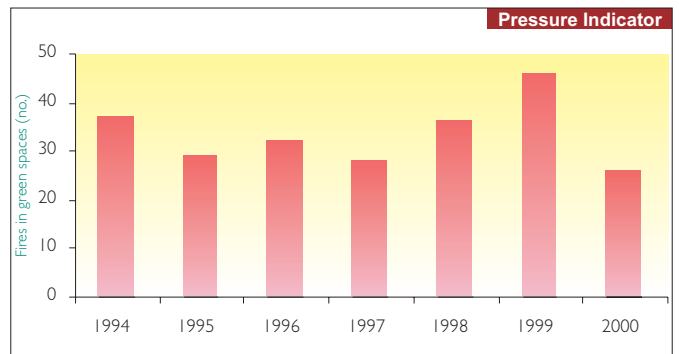


Figure 5.6
Number of fires in green spaces
(Sources: SCS, 2001)

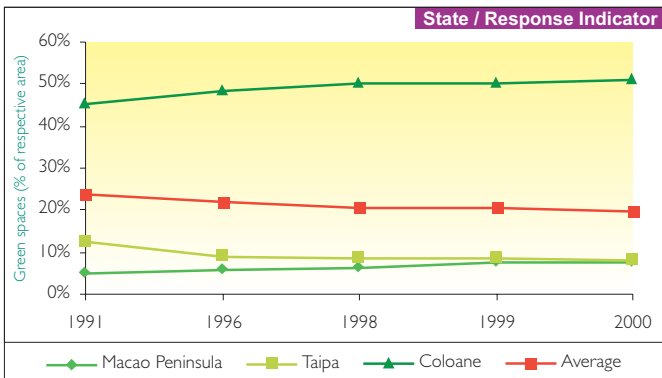


Figure 5.4
Percentage of the respective region covered by green spaces
(Source: PMM, PMI, SCS, 2001)

5.2 Forest Fires

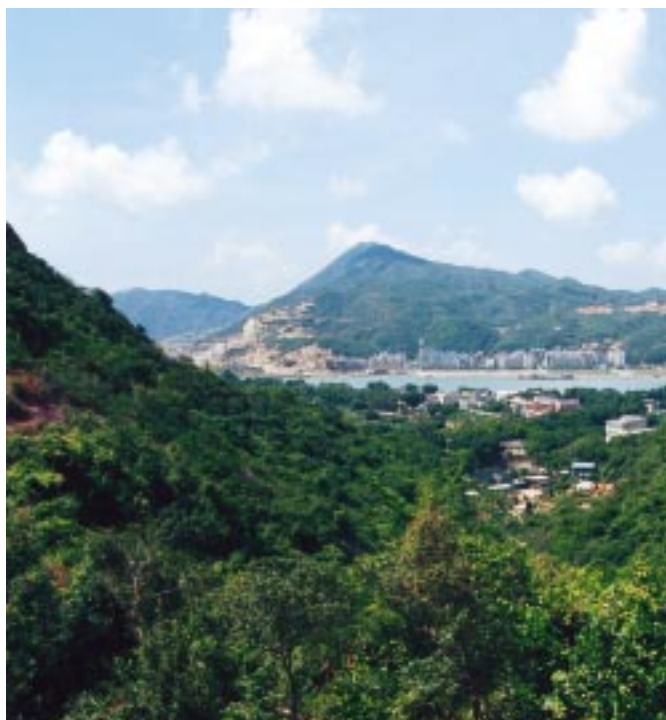
A spark can destroy the whole forest. Improper human activity is the main reason for most of the fires in the green area of Macao. Therefore, it is extremely important to promote the awareness of fire prevention among the public in order to keep the effort of reforestation in the past years. In 2000, a total of 26 fires, which is slightly lower than that of previous years, occurred in the green area of Macao.



5.3 Reforested Areas

Prior to the 1980's, the mountain areas of Taipa and Coloane were covered with pine trees (*Pinus massoniano*). However, it was found that these forests were being attacked by one cochineal insect (*scale insect*), causing innumerable pines to wither. With the suggestions made by the Guangdong Agriculture Department, the Agriculture and Forest Services of Macao started to cut down the affected pines in 1982 for the sake to create forest strips for new planted trees. In 1999, the PMI invited again the Guangdong Agriculture Department to carry out a thorough ecological and environmental assessment on the 360-hectare of reforested areas in Taipa and Coloane. The result of this assessment shows that the trees have grown healthy and play a very important role in absorption of dust, water soil conservation, enhancement of fertility, absorption of CO₂ and the release of oxygen. They, therefore, become the major component of the ecological environment in Macao, as well as locations for the public to enjoy the beauty of nature in leisure times.

Based on the statistics of 2000, the reforested areas consist of 29 species with a total number of 417,500 trees. On this basis, the Government plans to plant new trees that are more fire resistant, long-lasting and with higher appreciation value. In 2000, a 1,500m long walkway (*Lou Wan Seg Min Pun Gu Don*), in Coloane was built and opened to the public.



5.4 Ecological Invasion

In these recent years, the sign of *Mei Gem Gug* (*Mikania micrantha*) (commonly called the "Plants' killer") is detected in Macao and it is a creeper original of Central and South America that grows rapidly in an environment of high temperatures and humidity. This plant reproduces easily, creeping on other plants, shrubs or tree species; it blocks the sunlight and hence affects photosynthesis to take place, causing plants to wither gradually. At present, this plant has been spreading throughout Southeast Asia and the Pearl River Delta. Because it is an imported species, no natural enemy which controls its propagation has yet been found. Therefore, the only way to remove it so far is by artificial means.

Scientists have already commenced research on identifying solutions through ecological balancing, which means to introduce the natural enemy against *Mei Gem Gug* so as to maintain the equilibrium of the ecological environment. Similar cases also happen to neighbours of Macao, like Hong Kong, Zhuhai and Shenzhen. Therefore, long-term collaboration among these regions is recommended. The research on local vegetation species and their ecological structure should also be reinforced.



5.5 Nature Reserves

At the beginning of the 1980s, due to scientific, ecological, landscape and educational reasons, through the publication of Executive Orders nos. 33/81/M and 30/84/M, the Government of Macao constituted a reserve area of 198,000 m² in Coloane, the Seac Pai Van Park. The objective for the creation of this reserve is to provide sufficient resources to preserve the rare flora species in Macao and to develop new methods of vegetal plantation, which would enrich the varieties of species.

Regarding coastal ecology, since Macao is located at the southwest of the Pearl River Estuary, there is a wealthy sludge deposit of organic substances. Together with the influence of the brackish water and artificial and natural barriers in some parts of the coast minimizing the influence of winds and waves, it favors an ecological environment suitable for the growth of mangrove forests. In 1970s, a piece of 50-hectare valuable ecological mangrove forest was formed on the beach facing to the Praia da Taipa Avenue. That mangrove forest shrank up gradually due to the land reclamation in 1992. For the preservation of the mangrove forests, the PMI had transplanted part of the mangrove forests to the beach in front of the Jockey Club of Macao. Until 2000, four species including *Kandelia Candel*, *Algicera Corniculatum*, *Acanthus Illicifolius* and *Avicennia Marin*, can be found in that mangrove forest. Together with some other 290 plant species and previous birds searching for food, it reflects that the newly transplanted mangrove forests function well ecologically.

For effective protection on the mangrove forests of Macao, the Government has planned to construct a nature reserve of about 40 hectare, located at the west dike of Cotai, stretching from the future Yacht Club to the Coloane Wastewater Treatment Plant. There will be a green belt separating the nature reserves with the highways and hopefully, it will satisfy the needs of integrating ecology, education and tourism through all the planning criteria of Cotai.

5.6 CITES

In 2000, the Economy Department continued to cooperate with the Maritime and Customs Police Department to implement the treaty by inspecting and monitoring the trade activities of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Five processes covering import, export and re-export were handled.

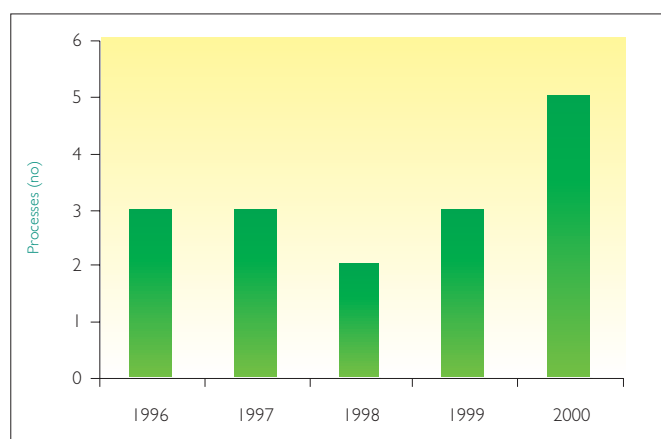


Figure 5.7
Number of processes handled by the Administrative Authority of CITES
(Source: ED, 2001)



6. Acoustic Environment

Noise is one of the main factors affecting urban environment and causes degradation of quality of life in the urban area. In most cases, it is the result of multiple contradicting users of limited public space and hence its resolution always lies with integrated approaches in city planning and public space management.

Noise pollution is one of the three major environmental complaints in Macao and data shows that the number of complaints has been increasing over the years.

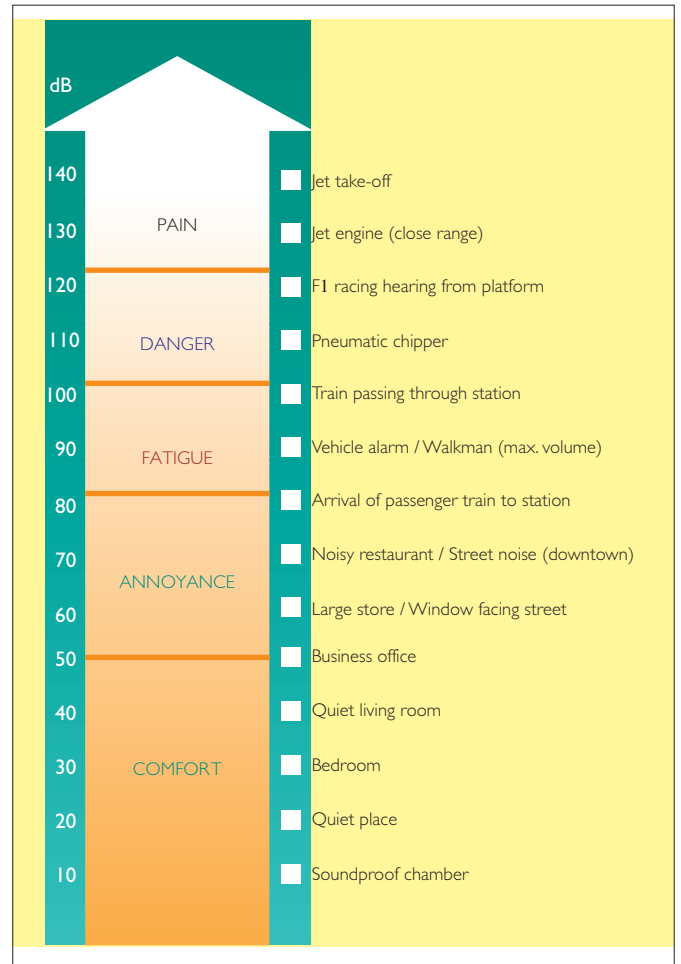


Figure 6.1
Noise scale
(Source: GDE, 2000)

6.1 Noise Monitoring

The Environment Council (EC), the Provisional Municipality of Macao (PMM) and the Provisional Municipality of the Islands (PMI) are the main authorities executing this task.

The locations and noise characteristics of the present monitoring points in Macao are listed in Table 6.1 .



Table 6.1. – Automatic noise monitoring stations and noise monitoring points in Macao (Source: EC, PMM, PMI, 2001)

MACAO PENINSULA		
Automatic Stations	Location	Characteristics
1	Horta e Costa Avenue	heavy traffic
2	Braga Street	ambient
Monitoring Points	Location	Characteristics
1	Venceslau de Morais Avenue	heavy traffic / industrial
2	Iao Hon Market Garden	leisure / residential / commercial
3	Intersection of Castelo Branco Ave. with Com. João Brito Street	commercial / industrial / residential
4	Camões Garden Square	leisure / residential / commercial
5	Ponte e Horta Square	residential / commercial / heavy traffic
6	Senado Plaza	leisure / commercial
7	Intersection of Campo Street with Pedro Nolasco Street	heavy traffic / residential/commercial
8	Intersection of Horta e Costa Avenue with Alm. Costa Cabral Avenue	heavy traffic / residential / commercial
9	1st October Square	residential / commercial
10	Penha Garden	residential / leisure
11	Intersection of Horta e Costa Avenue with Alm. Lacerda	heavy traffic / commercial / residential
12	Intersection of Barca Street with Adolfo Loureiro Road	residential / commercial
13	1st May Avenue	heavy traffic / residential
14	Dr. Carlos D'Assumpção Square	residential / commercial
15	Artur Tamagnini Barbosa Avenue	residential / heavy traffic / commercial
16	Praia Grande Avenue	heavy traffic / leisure
17	Amizade Avenue	heavy traffic / commercial
18	D. Belchior Carneiro Avenue	commercial / residential
19	Conselheiro Borja Avenue	traffic / school
20	Barra Street	residential / leisure
ISLANDS		
Monitoring Points	Location	Characteristics
1	Ouidor Arriaga Square, Taipa	heavy traffic
2	Bombeiros Square, Taipa	heavy traffic
3	Dr. Carlos A.C. Paes Assumpção Roundabout, Taip	heavy traffic
4	Presidente António Ramalho Eanes Square, Coloane	heavy traffic

The Environment Council has begun the “Macao Ambient Noise Automatic Monitoring Project” since 1999. This automatic monitoring system consists of two stations (3m measuring height) and one mobile station (4m measuring height), facilitating systematic collection of data in designated areas so as to set up a database for future policy making, legislation review, urban planning, studies and environmental impact assessment, etc. Monitoring data from October to December of 2000 are illustrated in Figure 6.2 to Figure 6.5.

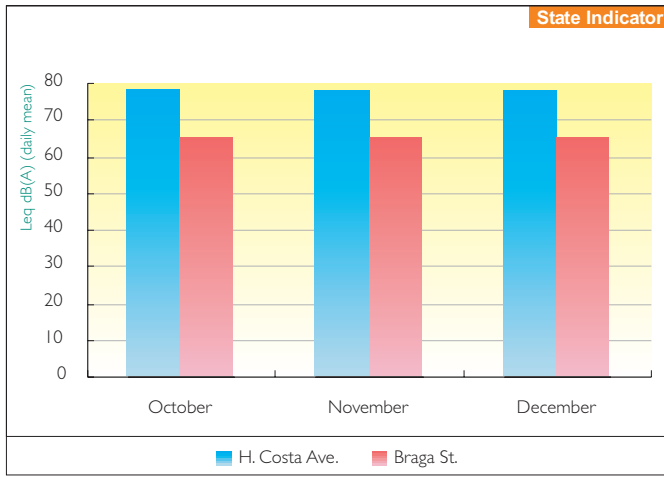


Figure 6.2
Daytime (8h to 20h) Leq (daily mean) of the automatic stations in 2000
(Source: EC, 2001)

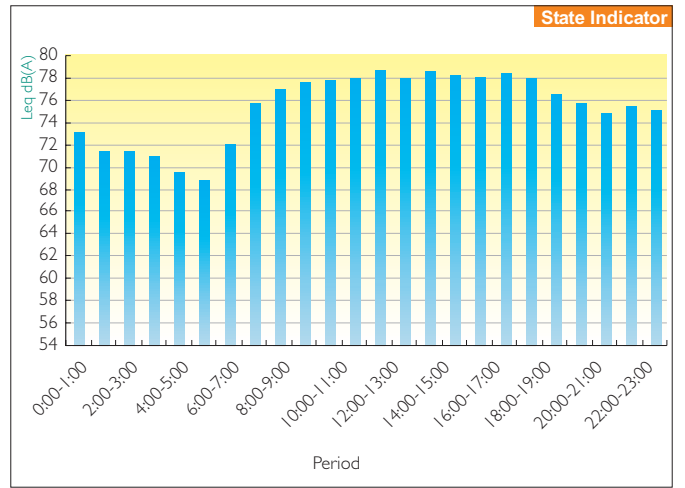


Figure 6.4
Hourly Leq (monthly mean) in the Horta e Costa Avenue station in October 2000
(Source: EC, 2000)

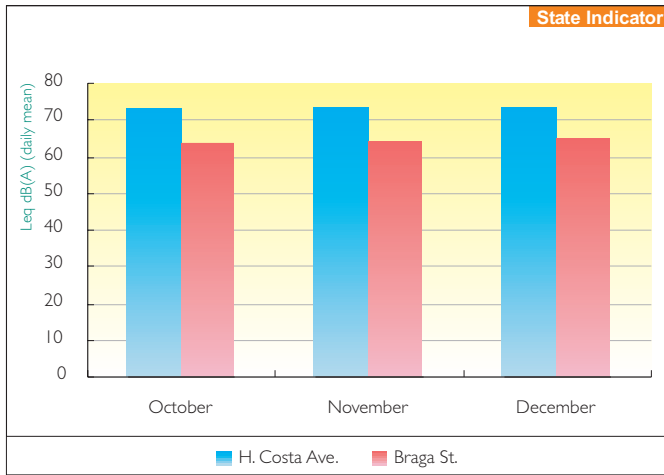


Figure 6.3
Night-time (20h to 8h) Leq (daily mean) of the automatic stations in 2000
(Source: EC, 2001)

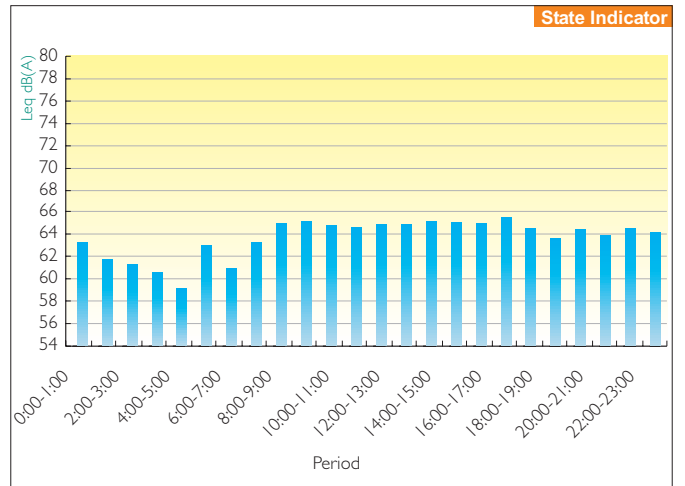


Figure 6.5
Hourly Leq (monthly mean) in the Braga Street station in October 2000
(Source: EC, 2000)



Table 6.2. – Monitoring data of Automatic Noise Monitoring Stations (Source: EC, 2001)

Month	L ₁₀ dB(A)		L ₅₀ dB(A)		L ₉₅ dB(A)	
	H. Costa Ave	Braga St.	H. Costa Ave	Braga St.	H. Costa Ave	Braga St.
October	78.1	65.9	73.3	59.2	61.8	50.7
November	78	65.8	73.2	59.3	61.5	50.3
December	77.9	66.1	73.1	59.6	62.1	50.2

Table 6.3. – Noise measuring parameters expressed in dB (A) (Source: SoER Portugal, 1994)

L _{eq} dB (A)	Continuous equivalent sound pressure level
L ₁₀ dB (A)	Sound pressure level exceeded for 10% of the measuring time (Higher intensity peak indicator)
L ₅₀ dB (A)	Sound pressure level exceeded for 50% of the measuring time
L ₉₅ dB (A)	Sound pressure level exceeded for 95% of the measuring time (Background noise indicator)

Three commonly used noise scales and their respective monitoring data from October to December in 2000 are listed in Table 6.2 and 6.3, reflecting certain characteristics of the ambient noise level in Macao.

The Provisional Municipality of Macao has started a noise monitoring scheme in selected locations (1.2m measuring height) during daytime (8h to 20h) since 1997(see SoER 2000). Measurements are carried out in four different periods:

- D1 – from 08h to 11h
- D2 – from 11h to 14h
- D3 – from 14h to 17h
- D4 – from 17h to 20h

Industrial areas, residential areas and districts with heavy traffic are among the targeted monitoring points.

In 2000, 849 measurements were carried out in 20 monitoring points in the Macao Peninsula. Reading results revealed that there were 12 points with Leq over 70dB(A), showing a decrease of 3 points if compared with 1999. However, there were still 3 monitoring points with Leq over 75dB(A). All of them are located at districts with heavy traffic such as Point 7 (Intersection of Campo Street with Pedro Nolasco Street), Point 8 (Intersection of Horta e Costa Avenue with Alm.

Costa Cabral Avenue) and Point 11 (Intersection of Horta e Costa Avenue with Alm. Lacerda). The lowest sound pressure level was recorded at Point 10 (Penha Garden), a residential area with scarce commercial activities and traffic. (Figures from 6.6 to 6.9)



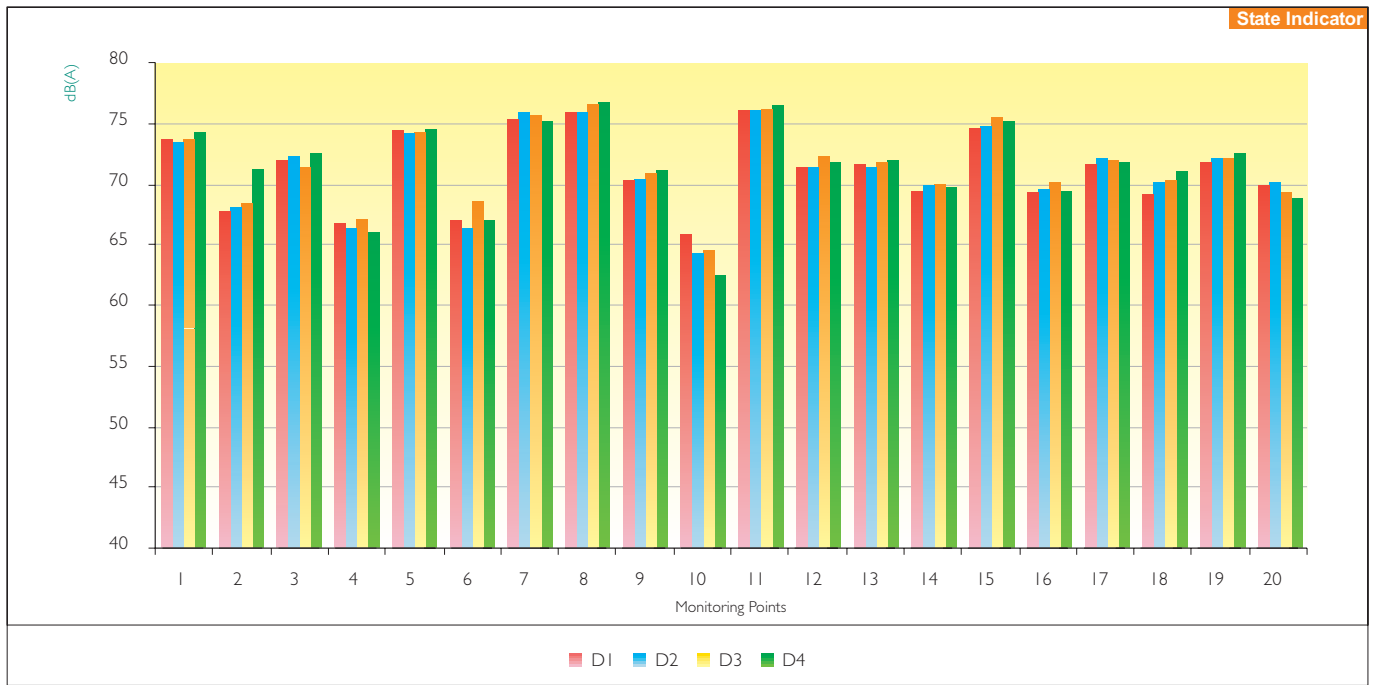


Figure 6.6
Comparison of sound level in the monitoring points located at the Macao Peninsula in 2000
(Source: PMM, 2001)

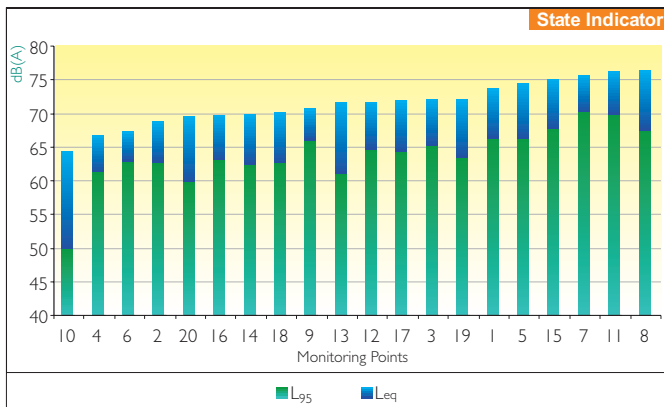


Figure 6.7
Leq and L95 on the Macao Peninsula in 2000
(Source: PMM, 2001)

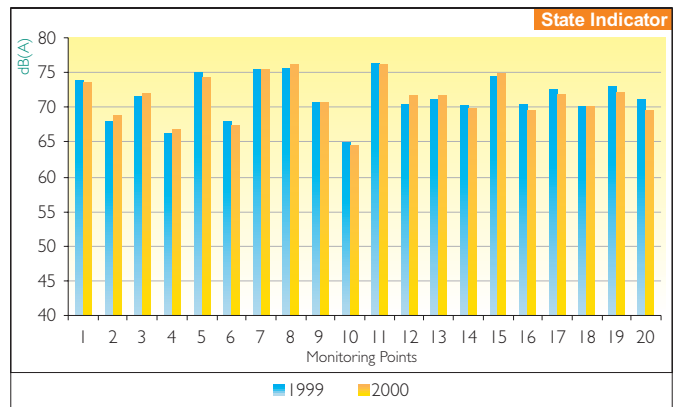


Figure 6.9
Comparison of Leq in 1999 and 2000
(Source: PMM, 2001)

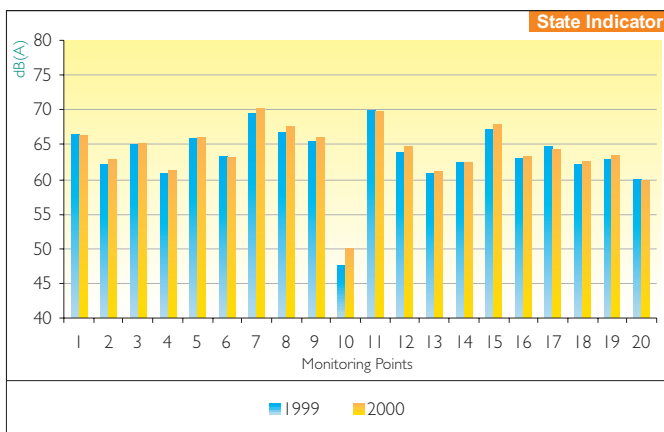


Figure 6.8
Comparison of L95 in 1999 and 2000
(Source: PMM, 2001)



Since 1998 the Provisional Municipality of the Islands has been carrying out daytime noise measurements (1.2m measuring height) in districts with heavy traffic in Taipa and Coloane (Table 6.1). Reading results of 2000 showed that all of the 3 monitoring points in Taipa were with Leq over 70dB(A), which is similar to the situation in 1999. Yet it is worth mentioned that the sound pressure level of Point 3 (Dr. Carlos A.C. Paes Assumpção Roundabout, Taipa) and Point 4 (Presidente António Ramalho Eanes Square, Coloane) has decreased since 1998.

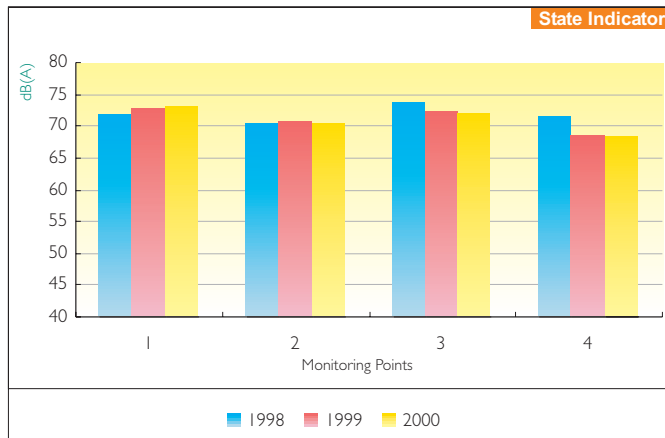


Figure 6.10
Comparison of daytime Leq (annual mean) in the monitoring points of the Islands
(Source: PMI, 2001)



6.2 Noise Complaints

Most complaints on noise discomfort are being addressed to the Police Department (PD), the Environment Council (EC), the Provisional Municipality of Macao (PMM) and the Provisional Municipality of the Islands (PMI).

In the year 2000, the PD (department receiving most complaints on noise) recorded 1,930 complaints, representing an increase of 62% in relation to 1999. Such increase refers essentially to the categories of “Music”, “Karaoke”, “Conversation” and “Mahjong” during night time.

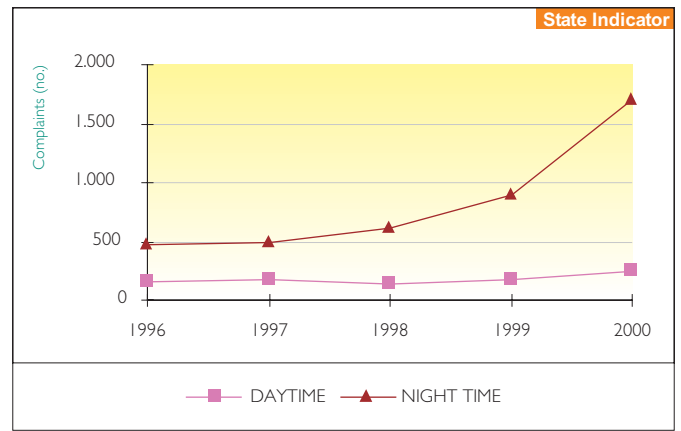


Figure 6.11
Evolution of the number of complaints on noise submitted to the PD
(Source: “Lotus”, Magazine on the Environment, 2000)

In 2000, the total number of complaints on noise addressed to the four mentioned authorities was 2,084, of which 87% were happening at night time (20h to 8h), referring mainly to the categories of “Music”, “Karaoke”, “Conversation”, “Mahjong” and “Works”. Another 13% happening at daytime are mainly due to “Works”, “Civil Constructions” and “Music”, with “Works” being the most significant category.

However, it should be emphasized that a certain amount of complaints were repeatedly made to the same noise source.

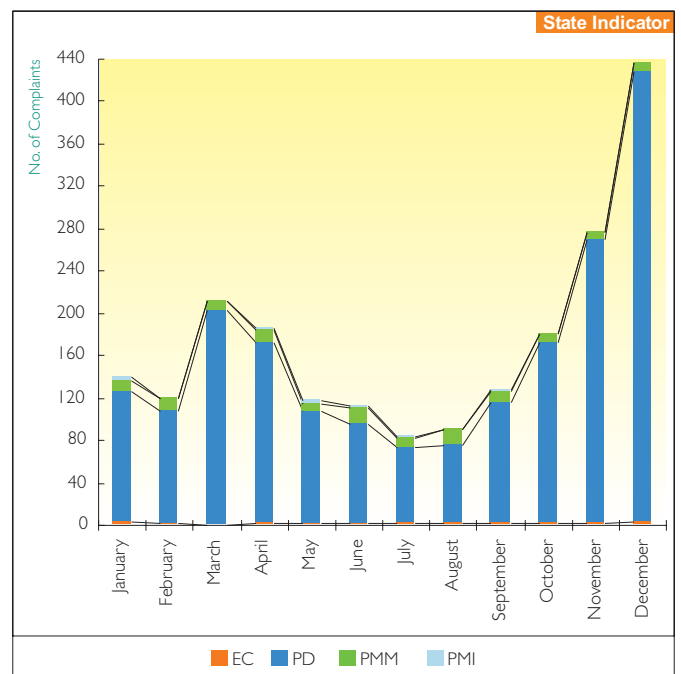


Figure 6.12
Number of complaints on noise in 2000
(Source: PMM, PMI, 2001; Lotus, Magazine on the Environment, 2000)

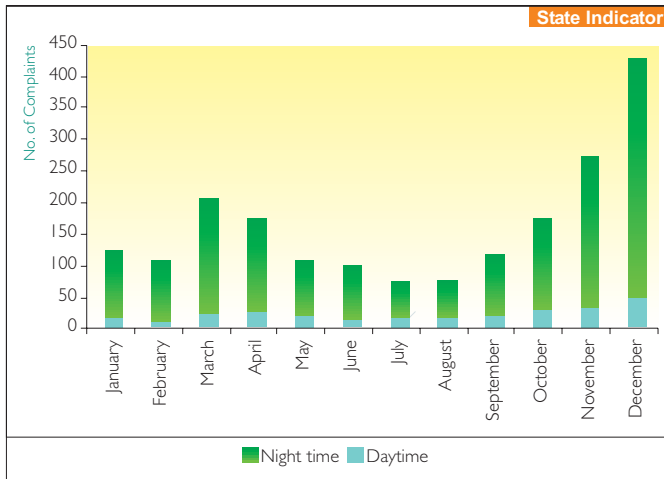


Figure 6.13
Number of complaints submitted to the PD in 2000
(Source: Lotus, Magazine on the Environment, 2000)

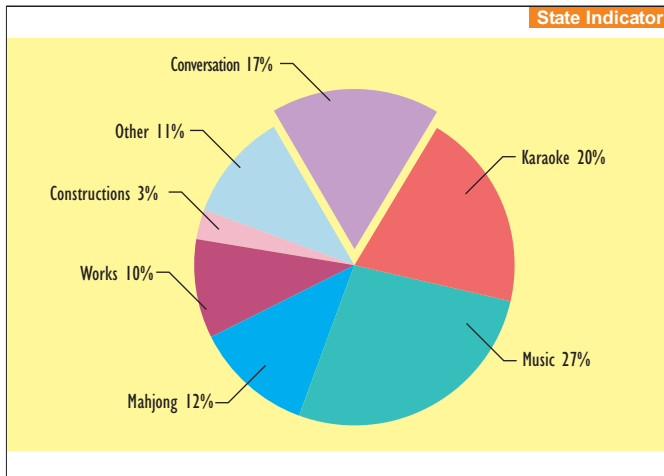


Figure 6.14
Complaints on noise submitted to the PD in 2000 by category
(Source: Lotus, Environment Magazine, 2000)

6.3 Noise Abatement Measures

Macao is a small and highly populated city where high-rise buildings are situated at sides of streets with heavy traffic. The continuous increase of vehicles accompanied by economic growth has exaggerated problems caused by traffic such as congested and noisy streets, which is very difficult to overcome.

There are direct and indirect approaches to reduce road traffic noise. The direct measures include study on implementation of vehicle noise standard, installation of acoustic barriers and the construction of anti-noise road surface etc. Traffic flow management, traffic planning and restructuring of road networks are among some of the indirect measures.

With a view of diminishing discomfort on residents caused by traffic noise, acoustic barriers of 511 metres were installed along the fly-overs of Artur Tamagnini Barbosa Avenue and Horta e Costa Avenue. This project started in 2000 by the Lands, Public Works and Transport Bureau and finished in May 2001.

Although road traffic noise is one of the main sources of noise pollution in Macao, it is certainly not the only one. "Music", "Karaoke", "Works", "Mahjong" and "Conversations" are, as already shown, other causes of noise complaints submitted to the responsible authorities. The abatement of all these kinds of noise undoubtedly depends on intense civil and environmental education, as well as the improvement of legislation and regulations.

As regards the noise caused by commercial and industrial activities, their reduction depends on certain factors such as introducing specific and rigorous evaluation criteria when granting operation licenses, enhancing technical support and implementing the legislation already in force. Also, preventive measures should gain priority under circumstances that without which, there would be adverse impacts on the environment and public health.

It is also necessary to intensify the collection of noise monitoring data so as to make grounds for manipulation of feasible noise control standard for Macao.





7. Environmental Management

The environmental policy of a country or a region becomes effective only if an integration of its environmental concerns extends to other sectoral policies and the whole society (including enterprises, public administration, non governmental organizations and citizens, etc.) should play their own role in obtaining a good quality of life.

However, setting up of legislation and promoting activities by responsible environmental entities are not enough. Other measures such as environmental education, training and promotion, public participation, the auto control of economic activities (complemented with efficient inspection), the mechanisms of voluntary participation (an example is the ISO 14000 standard environmental management system) and investments in research and development projects, etc. will be the effective instruments in gradual implementation of environmental management in Macao in the medium or long run.

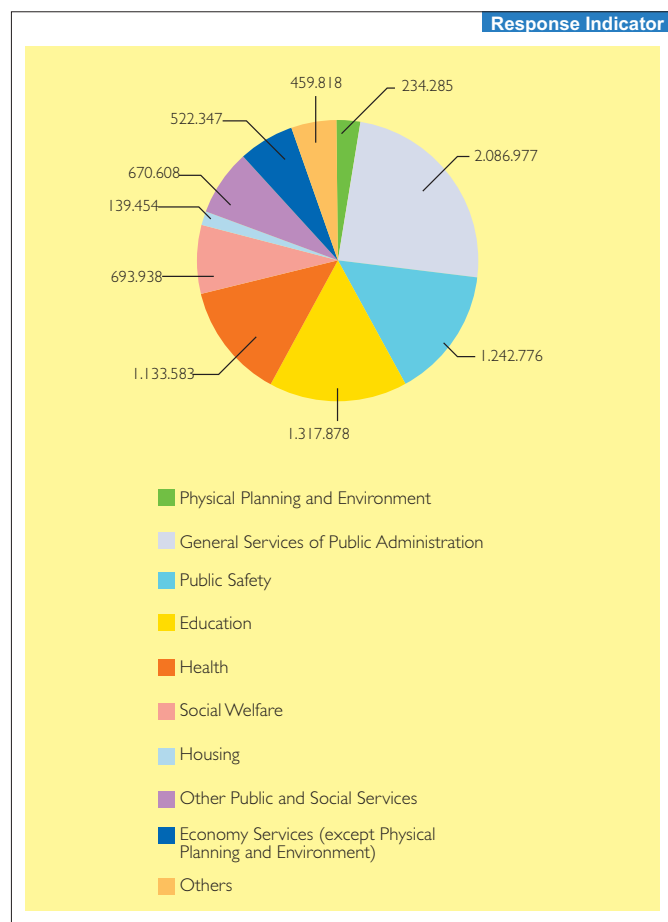


Figure 7.1
Public expenditure (in thousand patacas) by sector in 2000
(Source: FD, 2001)

Besides, with the globalisation, it is of the utmost importance that collaboration and planning should be in consensus between countries and regions since there is no boundary in pollution. Inadequate pollution measures in certain regions will incur environmental, economic and social repercussions in their neighbouring regions.

7.1 Investments and Expenses on Environmental Management

In 2000, the investments on physical planning and the environment is 2.8% of the total Public Administration expenditure. Comparing to the figure in 1999, there is a 1.5% decrease. If a comparison of the evolution of the different expenditure items is to be made since 1990, the physical planning and the environment sector has nevertheless grown more than all the other discipline (Figure 7.2).

Investments made by the two municipalities in 2000 on the environment have also declined, showing a decrease of 2.9% for the PMM and 2.1% for the PMI.

Despite the decline in environmental expenses, measures such as the environmental noise monitoring network, air quality monitoring and geographical information system have been developed so as to improve the living quality of the people.



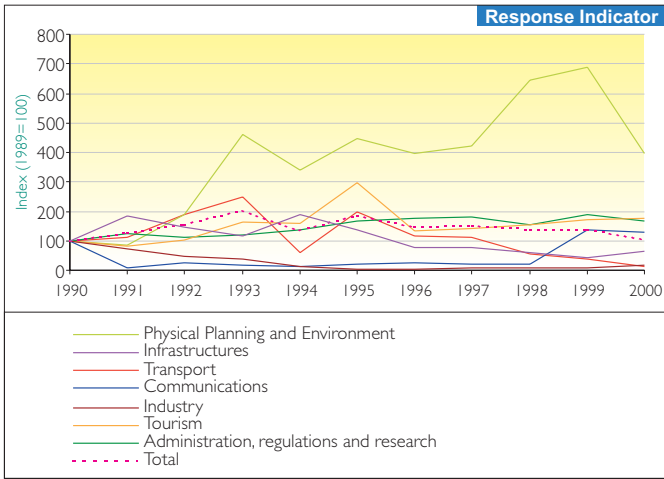


Figure 7.2
Evolution of public expenditure by sector since 1990
(Source: FD, 2001)

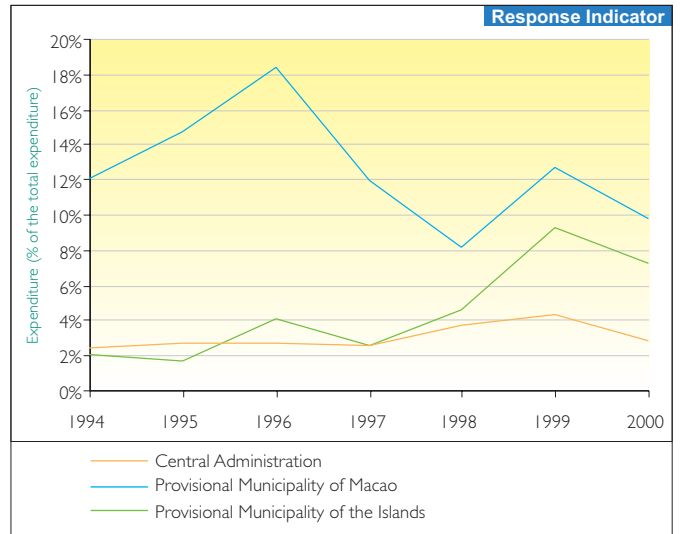


Figure 7.4
Comparison of the evolution of the expenditure percentages on physical planning and environment to the total annual expenditure
(Source: FD, PMM and PMI, 2001)

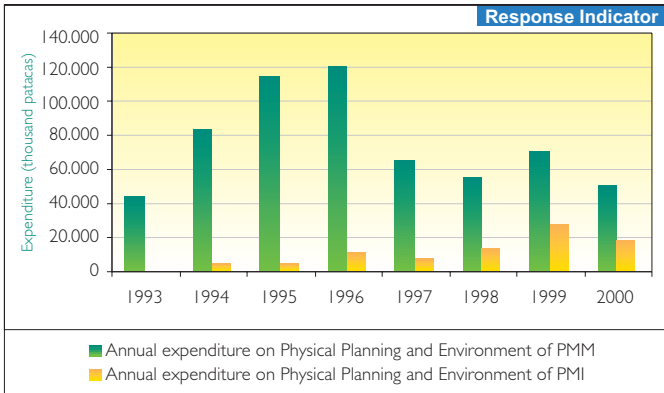


Figure 7.3
Expenditure of the PMM and PMI on physical planning and environment
(Source: PMM and PMI, 2001)



7.2 Environmental Awareness and Education

As mentioned in Agenda 21, no matter it is individual, association, enterprise or even the government, they should play their roles in the mission of getting the society towards sustainable development.

Therefore, it is necessary to reinforce and promote environmental awareness and training activities. Solutions to problems threatening the environment should be found and measures should be taken to prevent the deterioration of the environment.

The main objective of the activities on environmental promotion and education is to encourage citizens to be environmentally aware and concern about the balance of nature, since the state of the environment is closely related to human activities and social development.

Different kinds of environmental education activities have been developed in Macao for many years. The main entities involved are the Provisional Municipality of Macao, the Provisional Municipality of the Islands, the Education and Youth Department and the Environment Council. Regarding education in schools, the Education and Youth Department has been implementing some profound and wide-ranging activities. The main objective is to develop students into environmentally responsible individuals and be more energetic in environmental activities participation.

It is worthwhile to address the efforts made by the Environment Council in inter-regional collaboration issues. Projects with Hong Kong, Guangzhou, Shenzhen, Zhuhai and other cities of China have been launched and the celebration of the "World Environmental Day", a collaboration activity in environmental promotion, is a good example. These inter-regional projects are important tasks of the MSAR and no matter in the present or in the future, it is through these joint efforts that the regional environment can be improved.

In 2000, each entity has continued to develop a variety of environmental education activities. Statistics show that both the number of activities and the number of participants have been increasing. The two Provisional Municipalities and the Environment Council have organized a number of 425 different types of activities, congregating about 205,000 participants.

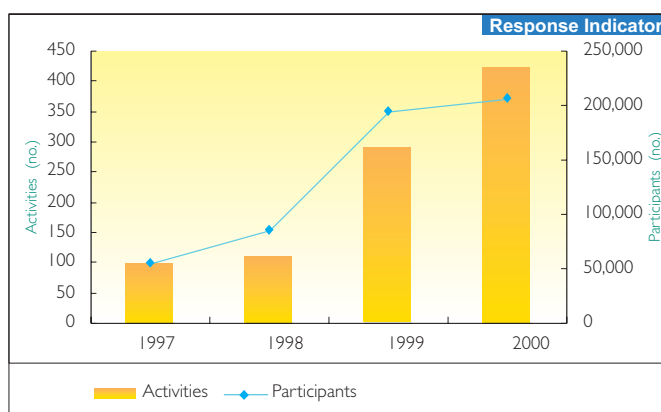


Figure 7.5
Environmental awareness and education activities organized by the PMM, PMI and EC
(Source: Statistics on the Environment, SCD, 1998-2000)



Quite a number of publications are issued by different entities and they are available to both students and the public for reference on environmental protection. For example, the promotion of "The Adventures of Mr. Garbage" is carried out throughout 9 different schools in 2000 with the aim of introducing students about waste treatment in Macao. In addition, other environmental information has also been published in electronic means (VCD and Internet), so that they may be readily available to the public.

Under the guidance of the Education and Youth Department, the *curricula* of the study courses aim at the integration of environmental concerns within various subjects, in such a way that students learn about their surrounding environment and the solutions to environmental problems. During the school year of 2000/2001, several courses are being held, such as "A Path for Growth---Saving the World", "Emissions and Energy", "Camp on Environmental Protection" and the "Scientific Summer Camp". Several hands-on projects with recyclable materials had also been carried out.

In addition, the Environmental Information Centres managed by the two municipalities and the Centre of Studies and

Education Resources of the Education and Youth Department are important to the environmental education in Macao. For example, the Environmental Information Centre offers small multifunctional teaching centres to facilitate the public, teachers and students with environmental knowledge.



Table 7.1 Major environmental education activities in 2000 (Source: EC, PMM, PMI, EYD, 2001)

ACTIVITIES
<ul style="list-style-type: none"> • City Cleaning Campaign • The 19th Green Week • Earth Day Celebration • Environment Day Celebration. Joint awareness-raising activities, among two regions and three cities, on the theme of "Let's Share Clean Air" • Environmental Camp for the Youth • Opening of the Flora Garden "Ecoteque" • Paper Recycling Month • Launching of the "Environmental Geographical Information System" of Macao • Environmental Teenage Ambassadors
PUBLICATIONS
<ul style="list-style-type: none"> • Lotus, Journal of Environment <ul style="list-style-type: none"> • Volume 13. Environment and Living Quality • Volume 14. Focus on the Environment of the Pearl River Delta • Volume 15. Climate Change and Environment • Volume 16. ISO 14000 Environmental Management System • Report on the State of the Environment of Macao 2000 • Trees of Macao, vol. 3 • Newsletter on the Environment • Environmental Series : The Adventures of Mr. Garbage
VCDs
<ul style="list-style-type: none"> • The Water Cycle

Any activity that assists the citizens in raising their environmental awareness and improves their consumption pattern is very important and this is particularly crucial in Macao. Since the geographical size is small, the increase in waste production would pose treatment problems about which citizens should be concerned.

With the support from other entities, the Provisional Municipality of the Islands continued the paper-recycling project in 2000. The number of schools participating in this project has been increasing, reflecting acceptance and support of the issue from the academic.

The Provisional Municipality of Macao had also launched the waste recycling scheme in 1999, aimed to recover and reuse of waste such as plastic, paper and aluminium cans. The scheme was successfully carried out in 2000 and the amount of recycled waste has increased. Several hotels, government departments and residential buildings participate in the scheme and new types of waste containers are being introduced.

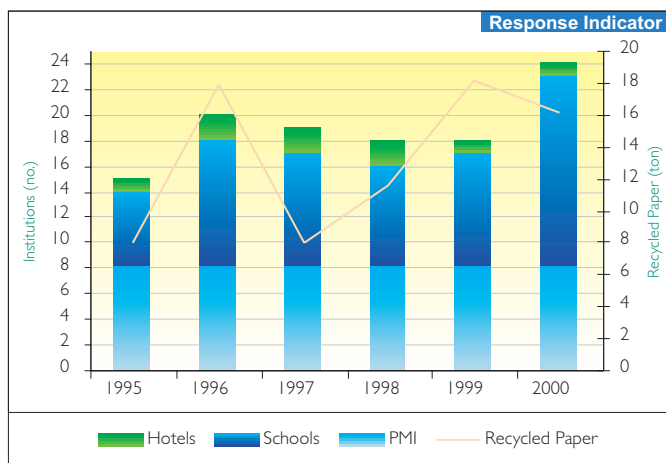


Figure 7.6
Paper Recycling Campaign of the PMI
(Source: PMI, 2001)

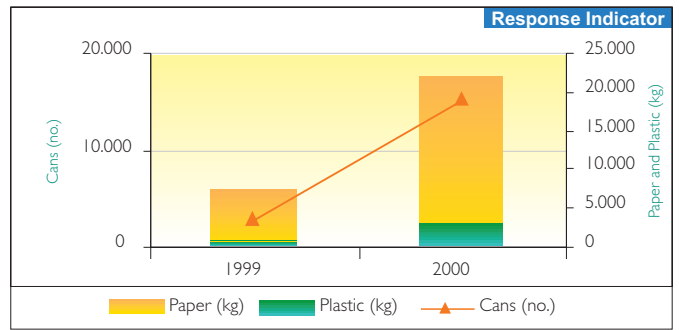


Figure 7.7
Waste recycling scheme by the PMM
(Source: PMM, 2001)

Visits to the wastewater treatment plants and waste incineration plant enable citizens to understand the concept of "Prevention over Remediation" towards solving environmental problems. In 2000, the number of visitors to the Macao Incineration Plant and the Macao and Taipa Wastewater Treatment Plant has increased.

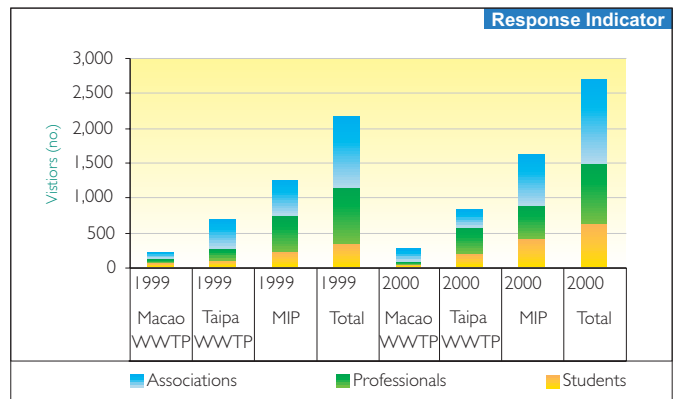


Figure 7.8
Number and type of visitors to the WWTP and the MIP
(Source: OID, 2001)



The complaints of the citizens to the responsible environmental parties reveals their concerns and responsibility with their quality of life being affected. From 1997 to 2000, complaints made to the PMM, PMI and EC have increased. Besides, the amount of inspection work also increased accordingly. This indicates that there is still a lot of efforts to be exerted in Macao in the cleaning and environmental aspect.

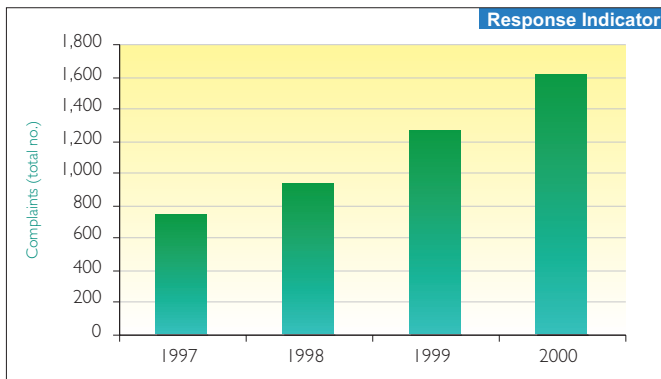
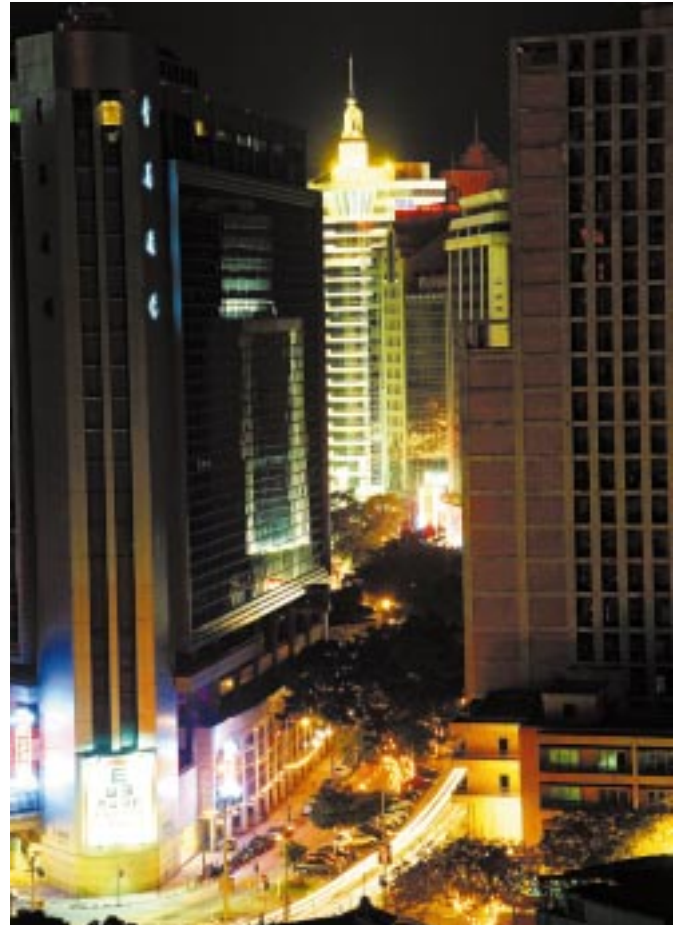
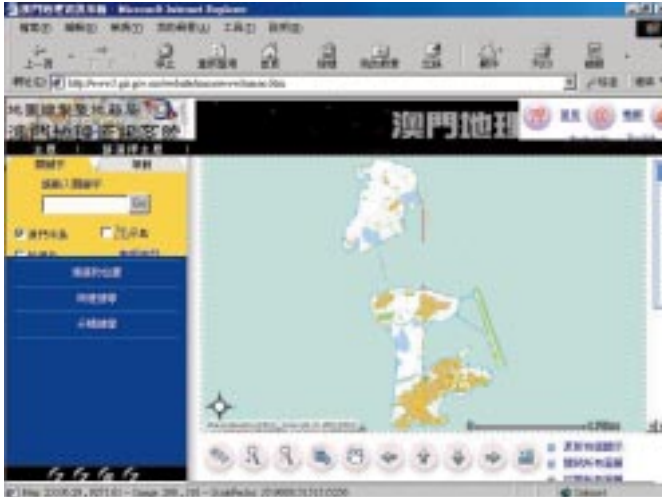


Figure 7.9
Complaints on the environment
(Source: PMM, PMI and EC, 2001)

7.3 Environmental Geographic Information System

The Environmental Geographic Information System (GIS) of Macao is a management tool, which allows various types of identified users (general public, government departments, participating entities in the project and government decision sectors) to access different levels of geographical and environmental information. Its ultimate objective is to establish a better environmental data and information database in Macao.

The GIS is a joint effort between the Environmental Council and the Cartographic and Land Registration Department since 1999. In 2000, besides reinforcing the hardware facilities, the security system has also been strengthened for data retrieval from the Internet. This system is designed to collect, store and analyse environmental information such as air quality index, air pollutants, meteorological data, potable water data, wastewater treatment capacity, waste and environmental noise monitoring etc.. Entities contributing data to the system include the Meteorology and Geophysics Department, the Office for Infrastructure Development and the Macao Water Supply Company.



7.4. Implementation of ISO 14001 Standard

The implementation of environmental management systems at entrepreneurial level is one of the best instruments for minimizing the adverse environmental impacts resulting from human activities. Their implementation leads to the conservation of natural resources by controlling the use of resources and raw materials, wastewater and waste generated, and at the same time with lowered production costs in medium or long term.

ISO 14001, an Environmental Management System standard, is defined by the International Organization for Standardization (ISO) and its objective is to improve continuously on the environmental performance of the organizations. To obtain the certification of this standard is by implementing a cyclic process of periodical review and assessment of the environmental management system based on the objective of continuous improvement. In fact, it is true that during the implementation process of this standard, organizations and companies will encounter numerous problems such as market competitiveness and product innovation.

In Macao, the Macao Productivity and Technology Transfer Center (CPTTM) has been organizing courses and seminars to promote and raise the consciousness of people regarding the standard of environmental quality.

Up to June 2001, five local organizations have been certified with ISO 14001 Standard.

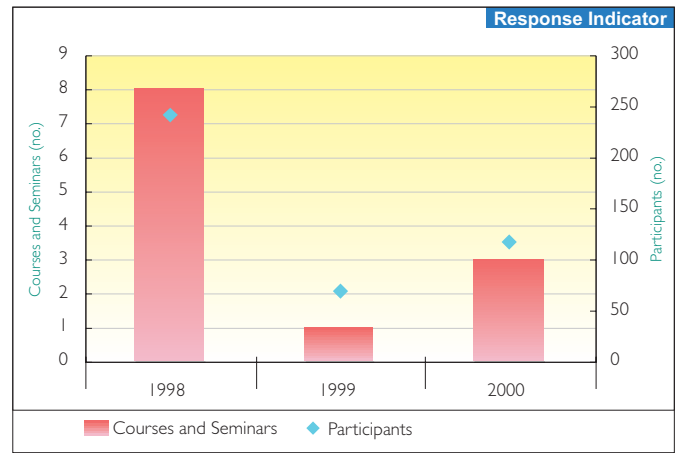
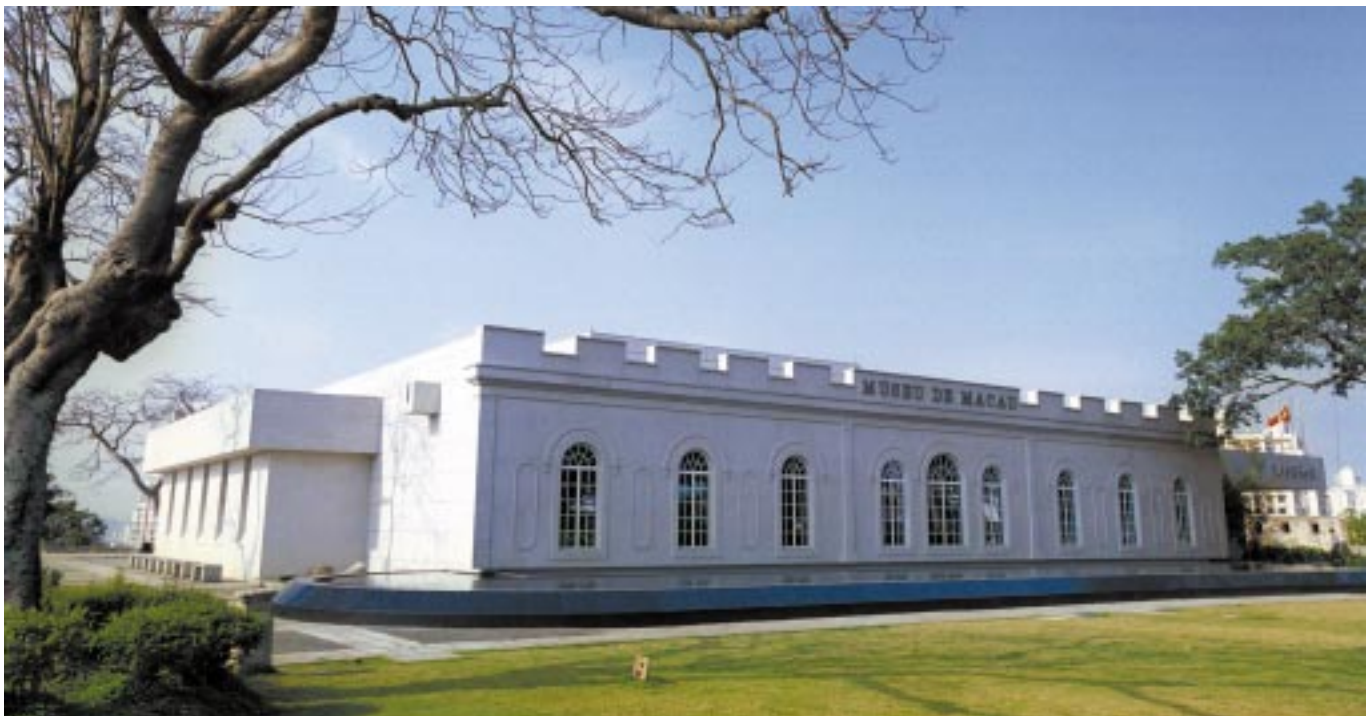


Figure 7.10
Courses and seminars on certification of ISO 14001 Standard
(Source: CPTTM, 2001)

In the ISO 14001 implementation process, organizations can further implement Environmental Auditing (ISO 14010/14019) and Environmental Performance Evaluation (ISO 14030/14039). In the manufacture of products, there are the Life Cycle Assessment (ISO 14040/14049) and Environmental Labels and Declaration (ISO 14020/14029); while there is the Environmental Aspects in Product Standard (ISO 14060) for product inspection. When all of these standards are being implemented, it will provide a better prospect for the environmental management.





8. Recommendations

The major objective of this report is to describe the evolution of the state of the environment in Macao each year and the direction of development so as to enable analysts and decision-makers at various levels to retrieve and research related information. We, therefore, believe that it is necessary to include this recommendation in the report, which allows readers to have a quick reference or conducting an in-depth analysis.

Herein, we would like to emphasize that some recommendations in the last report mentioned that when considering sustainable development and environmental problems, it should not only be limited to local area. Since there is no boundary for pollution, it is necessary to consider other nearby regions when analysing environmental problems and finding possible solutions. This implies that when analysing present problems and making relevant policies, it is crucial to maintain a good collaboration relationship with other regions on environmental protection and sustainable development.



Atmospheric Environment

In 2000, the AQI once showed the occurrence of unhealthy air. However, the AQI cannot reflect the situation in heavily polluted zones with intense traffic. This reveals the needs to improve the monitoring of air pollution caused by road traffic.

In addition, among the 10 types of air pollutants included in the emission inventory in Macao, electricity production is the



main source of releasing 5 types of these pollutants (including CO_2 , NO_x , SO_x , TSP and PM_{10}). This not only signifies the portion of energy production over other industries, but also the needs to improve on the equipment used in the plants (the use of diesel and turbines over steam boilers) as well as the measures in emissions control. Therefore, it will be necessary to have a strategic investment on the control and reduction of emissions such as the consideration of fuel improvement.

The increasing number of private vehicles (especially the motorcycles) not only increases burden to the existing traffic condition, but also brings environmental impacts such as air pollution and noise pollution. The emissions and air quality data on CO, N_2O and VOC_5 (CO_2 and PM_{10} are also to be taken into account) has been demonstrating the above situation. A series of measures such as the introduction of unleaded petrol in 1994, the use of catalytic converters in 1995 and the application of low-sulphur fuel for diesel vehicles in 2000 have relieved the impact on the environment by reducing the emission of particulates, NO_x , VOC_5 and CO. However, these measures are still not sufficient to solve the problems caused by the growing traffic intensity. For the improvement of eco-efficiency and transportation safety, it is necessary to input resources when setting policies, such as the regulation on technical aspects, the control of the traffic volume and redesigning the road traffic. When considering the transport policy, it is crucial to consider environmental factors as well so as to achieve the target of "Sustainable Transport".

Regarding the topic of climate change, although Macao is not one of the participating parties in committing to the reduction of greenhouse gas emissions from 2008-2012, it is still facing atmospheric pollution problems (such as acid rain) and therefore, efforts should be reinforced in finding measures to reduce GHG emissions.

Water Resources

As far as potable water is concerned, it is necessary to pay attention to the high chloride (salinity) and trihalomethanes concentration as well as a low fluoride concentration. Furthermore, there is also the need to control the water distribution network so as to improve the water loss situation.

By the end of 2000, some zones are still not covered by the wastewater drainage system or not connected to the wastewater treatment plant, and therefore, part of the waste water has been discharged without proper treatment. In addition, due to the over-burden of the wastewater drainage system during peak hours, wastewater is being discharged directly into the estuary areas. The case is more severe during rainy season and the quality of coastal water and bathing beaches has reflected the situation. It is therefore suggested to increase the monitoring and control work.

The increasing level of nitrogen and phosphorous in the Pearl River Estuary causes the extent of eutrophication to increase year by year.

One of the possible measures to be taken on water resource management is to have an integrated management on coastal zones, including studies on the characteristics of the coast and identification of negative changes such as erosion (loss of sand from beaches) so as to conduct a whole watershed management.



Waste

Understanding the physical and chemical composition of the incinerated waste at the Incineration Plant is important to waste management. By identifying the types of waste and their sources, the consumption patterns of the population can be better understood and thereby, better waste management guidelines can be established by achieving the target of reduce, reuse and recycle.

It is also recommended to monitor the content of heavy metals, dioxins and furans from incineration emissions and to carefully analyse and treat the toxic components of the fly ash resulting from waste incineration.

For the consumption behaviour of Macao's citizens, a green consumption pattern should be promoted.

A well local waste management policy should be in parallel with that of neighbouring regions and to conduct a holistic approach on waste treatment methods such as recycling, recovery, reuse, incineration and landfill treatment.

Nature Conservation

Green spaces possess several important ecological and social values such as clean air, soil and water conservation, fertilization, absorbing carbon dioxide, releasing oxygen and providing citizens



a place for leisure activities and nature enjoyment. Therefore, a high priority should be placed on the management of these green spaces. Special attention needs to be paid on the protection of reforestation areas and their development by carefully selecting the fire-resistant plant species. In addition, research on preventing ecological invasion should be reinforced so as to protect the natural resources.

Simultaneously, efforts should be endeavoured to raise the fire-prevention awareness of the population through civic education because the major cause for the devastation of green areas is by deliberate activities.

In addition, it is necessary to reinforce the research and protection work on local zones with high ecological value and the new 40-hectare reserves at the west dike of Cotai should also be properly managed.

Acoustic Environment

Due to the fact that Macao is a densely-populated city with narrow streets and intense road traffic, the noise level is comparatively high as reflected in the noise monitoring data.

Traffic noise may be reduced through the implementation of direct and indirect measures. Some of the direct measures include the study of vehicles' noise standard, the installation of noise barriers and low-noise road surface. While management on the traffic volume, the planning of road networks and the restructuring of facilities are some of the indirect measures to reduce the noise level.

Besides road traffic noise, other noise sources include music, karaoke, constructions, mahjong and conversation etc. All noise complaints to the monitoring authorities are under the above categories. In order to minimize noise pollution, it is necessary to strengthen the civil and environmental education of the citizens, followed by revision of the relevant legislation.

For the abatement of noise generated by commercial and industrial activities, a holistic assessment on noise pollution should be conducted by the licensing department in the licence granting process. Technical training should be reinforced and in force legislation should also be promoted and implemented. Preventive measures should be done in advance to situations that adverse environmental impacts may arise.

For reasonable adjustment and remedy on the noise pollution problem in Macao, it is crucial to reinforce the accumulation of monitoring data for designing the most suitable noise pollution control standard for the region.

Environmental Management

Regarding special measures and specific items of environmental management mentioned in this report, such as improving the atmospheric and water environment or the management of waste etc., the effort will be more significant when there is a good collaboration relationship between regions. The implementation of environmental management system and environmental education can promote the co-operation between cities and regions. Furthermore, it is also necessary to conduct systemic environmental impact assessment and monitoring on designated projects.



ACRONYMS AND SYMBOLS

A			K	Ktonnes	Thousand tonnes
ADA	Administration of Airports		L	Leq	Equivalent Sound Pressure Level
AQI	Air Quality Index		M	MLRB	Mapping and Land Registry Bureau
As	Arsenic		ME	Ministry of the Environment (Portugal)	
B			MEC	Macao Electric Company	
BOD	Biochemical Oxygen Demand		MGB	Meteorological and Geophysical Bureau	
BOD ₅	5-day Biochemical Oxygen Demand		MIP	Macao Incineration Plant	
BS	Black Smoke		MLM	Municipal Laboratory of Macao	
C			MPV	Maximum Permissible Value	
Cd	Cadmium		MRV	Maximum Recommended Value	
CFCs	Chlorofluorocarbons		MWSC	Macao Water Supply Company	
CH ₄	Methane		N		
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora		N ₂ O	Nitrous oxide	
CO	Carbon monoxide		NGO	Non Governmental Organisation	
CO ₂	Carbon dioxide		NH ₃	Ammonia	
COD	Chemical Oxygen Demand		NMVOG	Non-methane volatile organic compounds	
CORINAIR	Core Inventory of Air Emissions		NO	Nitrogen oxide	
CPTTM	Macao Productivity and Technology Transfer Center		NO ₂	Nitrogen dioxide	
Cr	Chromium		NO _x	Nitrogen oxides	
D			O		
dB	Decibel, sound level		O ₃	Ozone	
DO	Dissolved Oxygen		OECD	Organisation for Economic Co-operation and Development	
E			OID	Office for Infrastructures Development	
EEA	European Environment Agency		P		
ESB	Economic Services Bureau		PA	Port Authority	
ETFC	Energy Total Final Consumption		Pb	Lead	
EGIS	Environmental Geographic Information System		PD	Police Department	
EMEP	Co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe		PFCs	Perfluorocarbons	
EPA	Environmental Protection Agency		PMI	Provisional Municipality of the Islands	
EU	European Union		PHL	Public Health Laboratory	
EYAB	Education and Youth Affairs Bureau		PM ₁₀	Respirable Suspended Particles (≤ 10.μm)	
F			PMM	Provisional Municipality of Macao	
FSB	Finance Services Bureau		PRC	People's Republic of China	
G			S		
GDE	General Directorate for the Environment (Portugal)		SARM	Special Administrative Region of Macao	
GHG	Greenhouse Gas		SCS	Statistics and Census Services	
GIS	Geographic Information System		SF ₆	Sulphur hexafluoride	
GDP	Gross Domestic Product		SoER	State of the Environment Report	
GWP	Gross Warning Potential		SO ₂	Sulphur dioxide	
H			SO _x	Sulphur oxides	
HB	Health Bureau		T		
HCl	Hydrochloric acid		THM	Trihalomethane	
HF	Hydrogen fluoride		TOE	Tonnes of Oil Equivalent	
HFCs	Hydrofluorocarbons		TSP	Total Suspended Particulates	
Hg	Mercury		TSS	Total Suspended Solids	
I			U		
IPCC	International Panel for Climate Change		USW	Urban Solid Waste	
ISO	International Organization for Standardization		V		
			VOC	Volatile Organic Compounds	
			W		
			WHO	World Health Organisation	
			WTP	Water Treatment Plant	
			WSC	Waste Service Company	
			WWTP	Wastewater Treatment Plant	

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ENVIRONMENT COUNCIL

Address : Rua de Sanches de Miranda n° 3 – Macau

Tel: (853) 725 134

Fax: (853) 725 129

E-mail: ca@ambiente.gov.mo

<http://www.ambiente.gov.mo>

