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SELLING THE BLUE SKIES: SOME REFLECTIONS ON AIR POLLUTION FEE POLICY IN TAIWAN

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ABSTRACT

The air pollution fee (APF) policy was currently introduced to abate urban air pollution in Taiwan. This article addresses the policy's fairness and effectiveness from the standpoint of air quality, fee collection method, and major funding programs. The APF policy is an unfair policy because its fee collection method does not take regional and seasonal differences in air quality into consideration. Moreover, the collection method does not reflect differences in emissions from various sources. The use of APF to abate pollution is ineffective because its funding programs do not target the causes of air pollution in Taiwan. The overall message of this article argues that the current APF policy should be totally revised. This article also suggests alternative control strategies based on scientific understanding of recent urban air pollution problems in Taiwan.

INTRODUCTION

Although several major regulatory and administrative strategies have been gradually implemented in the past 20 years to control the deteriorating air quality in Taiwan, the government has still failed to attain the National Ambient Air Quality Standards for ozone (O_3) and particulate smaller than 10 μm (PM10). In response to such situations, the Taiwan Environmental Protection Agency (Taiwan EPA) proposed a controversial "air pollution fee" (APF) policy in 1993 as an economic-incentive tool to control urban air pollution problems in Taiwan. The legal basis of APF is Article 10 of the 1992 Taiwan Clean Air Act Amendment (CAAA), which specifies that "air pollution fees should be levied by responsible governmental agencies in various levels based on the emission rates of various air pollutants." Article 14 of the 1992 Taiwan CAAA by-laws further specifies that "air pollution fees should be used solely for air pollution control." After two years of intensive debates, the Legislative Yuan passed the APF policy and the Taiwan EPA started to collect APF in July 1995. The following questions are some major subjects of debate over the APF policy: Is APF an efficient economic-incentive tool to reduce air pollution or just a new tax tool to raise revenues for financially-strained governments? Are environmental equity problems adequately addressed in the current APF policy in terms of fee collection and program funding? Will the APF policy really improve the ambient air quality in Taiwan? If it will, how soon will it happen? In this paper, we will first examine the current situations of ambient air quality to highlight potential urban air pollution problems in Taiwan. Then we will review APF's fairness to citizens and industries in terms of the differences in air quality and emissions among various regions of Taiwan. And we will review the effectiveness and feasibility of various APF-funded strategies of pollution control from our understanding of air pollution problems in Taiwan. Lastly, we will suggest alternative ways to combat urban air pollution problems in Taiwan based on scientific findings of certain air pollution research. We argue that sound air quality management programs should not deviate from the reality of air pollution problems in the areas. In this article, our critiques on the current APF policy in Taiwan are mainly derived from our understanding of air quality in Taiwan. Therefore, the viewpoints reflected in this article come more from the perspective of environmental science than from the perspective of rigorous policy analysis.

AMBIENT AIR QUALITY IN TAIWAN

In 1993, an old air monitoring network with 19 stations was recently replaced by a new network, the Taiwan Air Quality Monitoring Network (TAQMN), with 66 monitoring stations. Hourly air pollution levels can be obtained from the continuous measurements of SO_2, NO_2, CO, PM10, and O_3 at these 66 stations. The national air quality can be measured by comparing the air pollution levels with appropriate National Ambient Air Quality Standards (NAAQS) for each air pollutant (Table 1). The air quality analyses presented in this paper consist of two-year monitoring data from September 1993 to August 1995. Comparisons between regional air quality can be achieved by simultaneous comparisons of air pollution levels in the 8 air basins designated by the Taiwan EPA. The designated zones of these 8 air basins and their associated station numbers are: Zone I (Stations 1 to 15), Zone II (Stations 17 to 27), Zone III (Stations 28 to 35), Zone IV (Station 36), Zone V (Stations 37 to 42), Zone VI (Stations 43 to 60), Zone VII (Stations 62 to 63), and Zone VIII (Stations 65 to 66) (Fig. 1). Five monitoring stations with special monitoring purposes are Station 16, which measures concentrations along the sidewalk of a main traffic route (Traffic site); Station 25, which measures concentrations along the fence of a petrochemical complex (Industrial site); Station 47, which measures air quality at the downwind areas of Zone VI; and Stations 61 and 64, which measure air quality at national parks (Park sites).

1. PM10

Judging from annual and daily average concentrations, PM10 is the main air pollutant which deteriorates urban air quality in Taiwan. As shown in Table 2a, the annual average PM10 concentrations in four air basins (Zones III-VI) are about 8-25 $\mu g/m^3$ above the NAAQS for PM10. Furthermore, PM10 concentrations, which average 126 $\mu g/m^3$, are exceptionally high at the traffic site. In contrast, the PM10 concentrations average only at 40-45 $\mu g/m^3$ in two eastern air basins. The PM10 concentrations are particularly low at the national parks, averaging about 18-23 $\mu g/m^3$. As shown in Table 2b, the number of days with daily PM10 concentrations exceeding 125 $\mu g/m^3$ in one year is about 200 days for Zone VI, 95 days for Zone III and Zone V, and 40 days for Zone I. These results indicate that PM10 pollution is serious in all western areas of Taiwan

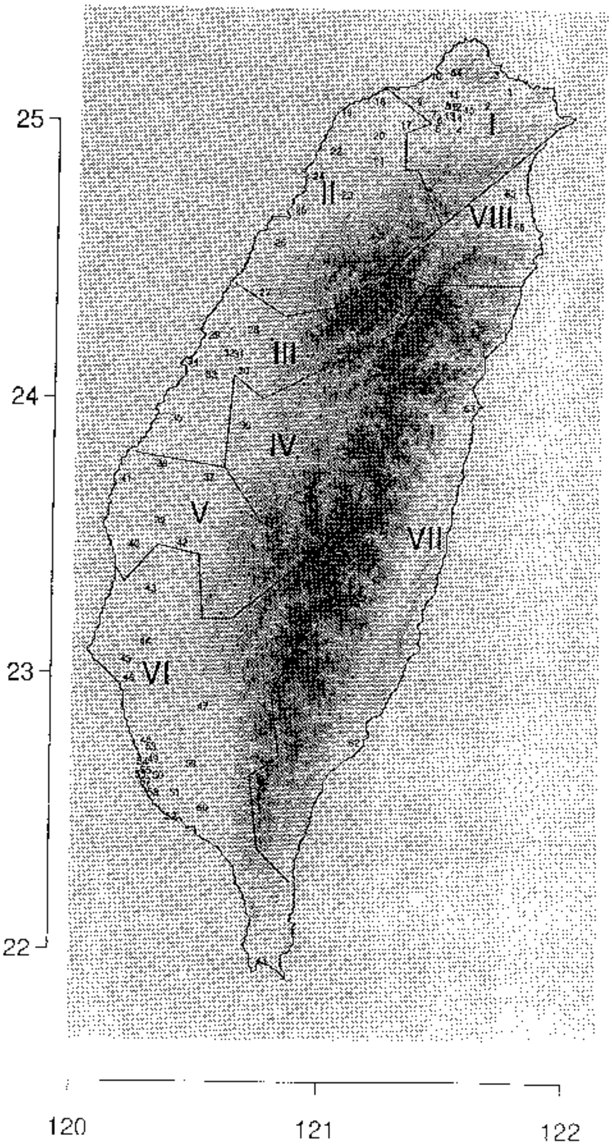

Fig. 1. Taiwan air quality monitoring network

and even more serious in the central and southern areas. Seasonal variation in PM10 concentrations is also very significant in Taiwan. For the four air basins with more serious PM10 pollution (Zones III-VI), summer is the season with the least PM10 pollution. The ratio of PM10 concentrations in the winter to that of the summer is about 2. Upwind-downwind pollutant transport is another particular feature of PM10 pollution. Geographically, Zone IV is located downwind of Zone III while Station 47 is a downwind site of Zone VI. Meanwhile, relatively few PM10 emission sources are reported in the areas surrounding Zone IV and Station 47. However, PM10 concentrations in both areas are very close to those of their neighboring upwind areas. Therefore, both Zone IV and Station 47 are thought to be the receptor sites of PM10 emissions from their upwind areas, which are Zone III and Zone VI, respectively.

Table 1. National Ambient Air Quality Standards (NAAQS) in Taiwan

Item	PM10		SO_2			NO_2		CO		O_3	
	1-Day average	Annual average	1-Hour average	1-Day average	Annual average	1-Day average	Annual average	1-Hour average	8-Hour average	1-Hour average	8-Hour average
Standard	125	65	0.25	0.1	0.03	0.25	0.05	35	9	0.12	0.06
Unit	$\mu g/cm^3$		PPM			PPM		PPM		PPM	

Table 2a. Average PM10 concentrations ($\mu g/m^3$) from 1993-1995 in 8 air basins in Taiwan

	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII	Traffic site	Industrial site	Sta. No. 47	Park site 1	Park site 2
Autumn	51.8	57.1	81.4	82.6	85.5	105.9	44.7	42.6	112.4	70.2	99.8	20.7	17.5
Winter	54.1	54.2	76.7	84.1	88.9	124.8	44.0	40.2	137.4	64.4	128.1	19.8	19.4
Spring	72.3	66.4	80.9	77.4	79.9	90.8	51.3	49.9	150.6	73.1	93.6	22.1	24.4
Summer	53.7	48.7	51.1	41.4	39.7	44.9	40.8	35.4	104.2	52.6	38.0	17.1	20.7
93/9–94/8	59.7	57.9	72.9	71.7	74.6	93.2	45.0	43.6	126.2	70.2	88.6	22.0	23.1
94/9–95/8	56.2	55.2	72.1	71.0	72.4	90.0	45.4	40.4	N.A.	60.0	91.1	17.8	17.9

Table 2b. Number of days with daily PM10 concentrations above 125 $\mu g/m^3$ from 1993-1995 in 8 air basins in Taiwan

	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII	Traffic site	Industrial site	Sta. No. 47	Park site 1	Park site 2
Autumn	9	6	55	16	69	145	0	0	31	1	37	0	0
Winter	25	29	63	20	73	160	0	0	55	8	93	0	0
Spring	48	28	65	9	44	90	0	3	69	7	39	0	0
Summer	3	1	6	0	0	2	0	0	19	0	0	0	0
93/9–94/8	51	37	91	23	91	199	0	0	174	11	76	0	0
94/9–95/8	34	27	98	22	95	198	0	0	N.A.	5	93	0	0

N.A.: not applicable

2. Ozone

Ozone is the second most important pollutant involved in the deterioration of urban air quality in Taiwan. As shown in Table 3a, the number of days with daily O_3 concentrations exceeding 120 ppb in one year is approximately 85 days for Zone VI and 30 days for Zone I. In contrast, daily O_3 concentrations are all below 120 ppb in the two eastern air basins. The results of 8-hour average concentrations show that ozone pollution is a serious problem in central and southern Taiwan. As indicated in Table 3b, the number of days with 8-hour average concentrations above 60 ppb are about 80-110 days for Zones I to V and 220 days for Zone VI. There is also a distinct seasonal effect on the ozone problem in Taiwan. The season with the worst ozone pollution is summer in the northern areas and autumn in the southern areas of Taiwan. Difference in meteorological conditions between the two areas is thought to be the main reason for such a phenomenon. During the dry season, summer in the north and autumn in the south, there is more sunlight for ozone production in the two areas. In addition, lower mixing heights are reported during the dry season in these two areas. A similar upwind-downwind transport effect is exhibited by ozone pollution as in the PM10 problem. Both Zone IV and Station 47 are receptor sites of O_3 produced in their upwind areas, which are Zone III and Zone VI, respectively. It is also worthwhile to note that the average O_3 concentrations ranged from 40 to 55 ppb in the national parks, which is even higher than the average concentrations in the two eastern air basins. In the long run, high O_3 concentrations may cause ecological damage to the national parks in Taiwan.

3. Sulfur Dioxide (SO_2)

Although the air quality in all air basins meets the requirements of the NAAQS for SO_2, relatively high SO_2 concentrations are measured at the industrial monitoring site. As indicated in Table 4a, the annual average SO_2 concentration ranges from 1 to 11 ppb for the 8 basins but ranges from 40-50 ppb for the industrial site. The ratio of SO_2 concentrations in the worse basins (Zones II and VI) to the better basins (Zones VII and VIII) is about 10. Since both Zones II and VI are major petrochemical industrial areas in Taiwan, stationary SO_x emissions are thought to be the main reason for the deterioration in the air quality in these two areas. The industrial

Table 3a. Number of days with 1-hr O_3 concentrations above 120 ppb from 1993-1995 in 8 air basins in Taiwan

	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII	Traffic site	Industrial site	Sta. No. 47	Park site 1	Park site 2
Autumn	6	13	15	14	7	68	0	0	N.A.	N.A.	10	0	0
Winter	0	0	0	0	0	28	0	0	N.A.	N.A.	3	0	0
Spring	21	7	3	2	1	43	0	0	N.A.	N.A.	13	0	2
Summer	34	7	4	1	1	29	0	0	N.A.	N.A.	1	0	2
93/9–94/8	33	19	11	6	4	81	0	0	N.A.	N.A.	14	0	3
94/9–95/8	28	8	11	11	5	87	0	0	N.A.	N.A.	13	0	1

N.A.: not applicable

Table 3b. Number of days with 8-hr O_3 concentrations above 60 ppb from 1993-1995 in 8 air basins in Taiwan

	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII	Traffic site	Industrial site	Sta. No. 47	Park site 1	Park site 2
Autumn	29	76	95	115	100	160	7	1	N.A.	N.A.	125	8	19
Winter	5	11	12	23	20	104	0	0	N.A.	N.A.	68	3	6
Spring	72	47	47	48	54	106	4	0	N.A.	N.A.	80	14	49
Summer	65	58	38	35	30	57	11	1	N.A.	N.A.	24	0	24
93/9–94/8	78	97	99	116	94	208	9	1	N.A.	N.A.	125	12	50
94/9–95/8	93	95	93	105	110	219	13	1	N.A.	N.A.	172	13	48

N.A.: not applicable

Table 4. Average SO_2 concentrations (ppb) from 1993-1995 in 8 air basins in Taiwan

	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII	Traffic site	Industrial site	Sta. No. 47	Park site 1	Park site 2
Autumn	6.0	12.5	7.7	4.2	5.6	11.5	2.5	1.1	18.3	60.0	4.3	1.0	3.2
Winter	5.7	11.9	7.0	4.2	6.4	15.6	2.2	1.1	18.1	64.9	4.4	1.8	1.6
Spring	8.8	10.1	7.2	3.5	4.8	11.6	2.4	0.8	16.6	30.0	3.7	2.2	3.0
Summer	9.2	8.7	5.1	2.3	2.8	7.0	3.0	0.9	18.8	21.2	1.5	1.4	4.1
93/9–94/8	7.2	11.1	7.0	3.6	4.8	11.8	2.5	1.0	18.0	48.2	3.6	1.6	3.0
94/9–95/8	7.6	10.4	6.5	3.4	5.0	11.0	2.5	1.0	N.A.	38.9	3.3	1.6	3.0

N.A.: not applicable

monitoring site violates the annual, daily, and hourly requirements of the NAAQS for SO_2, having 36-58 days with SO_2 concentrations above 100 ppb and 8-20 days with 1-hour SO_2 concentrations above 250 ppb within a two-year period. Since the monitoring station is located in a primary school, about 1,300 students and teachers are potentially exposed to unhealthy air quality during their school hours. Moreover, about 300,000 residents are potentially exposed to such high SO_2 concentrations in the area surrounding the monitoring station. For most air basins except Zones I and VII, the SO_2 concentrations in the winter are also found to be about 1.5 to 3.0 times higher than the SO_2 concentrations in the summer. In Zones I and VII, the SO_2 concentrations in the summer are the highest among four seasons. The seasonal difference in SO_2 concentrations is believed to be due to changes in mixing heights between seasons. The SO_2 concentrations measured at the traffic site, with annual concentrations between 15-18 ppb, are also relatively high in comparison to the average concentrations in the 8 air basins. SO_x emissions from diesel-powered vehicles are possible sources for the relatively high SO_2 concentrations on roads.

4. Carbon Monoxide (CO)

CO pollution is relatively mild in Taiwan in comparison to other pollutants. As indicated in Table 5, the annual average CO concentration in the metropolitan area of Zone I is only about 1 ppm. The differences in CO concentrations, about 30%, between air basins and seasons is not very significant, either. As expected, CO concentrations measured at the traffic site are relatively high because its main contributors are motor vehicles. The annual average concentration at the traffic site is about 5.5 ppm, which is about 5 times higher than the ambient average in Zone I. There are 58 days with 8-hour average CO concentrations above NAAQS within a one-year period at the traffic site. The results indicate that people commuting along the main roads in metropolitan areas are exposed to moderately high CO concentrations. High CO exposures for commuters in metropolitan Taipei were reported in one study by Liu *et al.* [1]. The CO concentrations in two national parks average 0.3 ppm, which may represent background CO concentration in Taiwan.

5. Nitrogen Dioxide (NO_2)

Judging from annual average concentrations of NO_2 in the 8 air basins, NO_2 pollution is moderately serious in Taiwan and very serious if judged from measurements from the traffic site. As shown in Table 6, the annual average NO_2 concentration ranges from 13 to 27 ppb for the 8 basins and is 54 ppb for the traffic site, which violates the annual NO_2 requirement for the NAAQS. The ratio of the NO_2 concentration in the 6 western air basins and the 2 eastern air basins (Zones VII and VIII) is about 2. The NO_2 concentrations in two national parks average 3 ppb, which may represent background NO_2 concentration in Taiwan. Apparently, the NO_2 concentrations are related to human and industrial activities in Taiwan. This is understandable since NO_x is mainly emitted from automobiles and factories. A better NO_2 air quality is also found in the summer among four the seasons. Again, this might be due to changes in climatic patterns between seasons.

Table 5. Average CO concentrations (ppb) from 1993-1995 in 8 air basins in Taiwan

	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII	Traffic site	Industrial site	Sta. No. 47	Park site 1	Park site 2
Autumn	0.9	0.6	0.9	0.9	0.7	0.8	0.6	0.7	6.0	N.A.	0.6	0.3	0.3
Winter	1.1	0.7	1.0	1.0	0.7	1.0	0.7	1.0	5.3	N.A.	0.7	0.4	0.3
Spring	1.2	0.8	0.9	0.9	0.7	0.8	0.7	0.9	5.6	N.A.	0.6	0.3	0.3
Summer	1.0	0.6	0.7	0.6	0.5	0.6	0.6	0.7	5.2	N.A.	0.4	0.3	0.3
93/9–94/8	1.1	0.7	0.9	0.8	0.7	0.8	0.7	0.9	5.5	N.A.	0.6	0.3	0.3
94/9–95/8	1.0	0.6	0.9	0.8	0.6	0.8	0.7	0.7	N.A.	N.A.	0.6	0.3	0.3

N.A.: not applicable

Table 6. Average CO concentrations (ppb) from 1993-1995 in 8 air basins in Taiwan

	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII	Traffic site	Industrial site	Sta. No. 47	Park site 1	Park site 2
Autumn	23.3	20.4	27.6	25.9	22.1	27.0	13.0	12.4	50.8	26.8	16.7	1.6	2.8
Winter	26.9	21.2	28.2	30.2	25.9	34.5	16.6	15.1	55.7	28.2	24.0	2.8	2.2
Spring	31.0	23.2	28.3	26.6	21.6	25.7	15.3	14.3	59.9	26.3	17.2	1.8	3.6
Summer	22.4	17.4	17.8	14.3	12.4	14.4	10.5	9.3	48.4	21.7	8.5	1.4	4.6
93/9–94/8	25.2	20.3	25.9	23.5	20.6	25.3	13.1	13.0	53.7	26.0	16.5	2.1	3.2
94/9–95/8	26.6	20.8	25.1	25.0	20.4	25.5	14.6	12.5	N.A.	25.5	16.6	1.7	3.4

N.A.: not applicable

6. Volatile Organic Compounds (VOCs)

In addition to criteria air pollutants, non-criteria air pollutants may also pose serious air pollution problems in Taiwan because of high traffic density. In 1994, it was estimated that there were 4.6 million cars and 11.9 million motorcycles in Taiwan. Emissions of hydrocarbons from these motor vehicles contain various air toxics including volatile organic compounds (VOCs). Since VOCs are not routinely measured by the Taiwan EPA, the air quality of these pollutants can be referred to a study by Chan *et al.* [2]. This study reported the annual average concentrations of 8 VOCs benzene, heptene, heptane, toluene, ethylbenzene, m/p-xylene, o-xylene, and isopropyl benzene in four monitoring stations in Taipei. The mean concentrations were about 5.8-7.7 ppb for benzene and 14.8-21.3 ppb for toluene. Another two studies also by Chan *et al.* reported that commuters were exposed to 19 VOCs, including benzene, while commuting and working in Taipei [3, 4]. The mean benzene concentration measured on buses was 58 ppb and 130 ppb on motorcycles. On average, commuters in Taipei experienced about 3-8 times higher VOC concentrations than did commuters in Los Angeles, California. The number of people risking cancer associated with commuter exposure to benzene was estimated to be from 7.5 -18 in one million in Taipei. Apparently, these studies have shown that vehicle-related VOCs are associated with the deterioration of air quality in metropolitan areas.

The ambient air quality is found to be significantly different among air basins and seasons in Taiwan. In general, the air quality in the island's eastern (Zone VII) and northeastern (Zone VIII) regions is much better than in other regions. The air quality in the summer is much better than other three seasons in the other most air basins except Zone I. PM10 and O_3 are two of the most important air pollutants involved in deteriorating urban air quality in Taiwan.

There is also a possible upwind-downwind effect on the transportation of these two pollutants in central (Zone IV) and southern (Zone VI) Taiwan. In industrial areas, the SO_2 pollution is still very serious. The pollution levels of all air pollutants are exceptionally high on the roadways of the metropolitan areas. Furthermore, commuters in metropolitan areas are exposed to very high concentrations of vehicle-related air toxics, such as benzene.

UNFAIRNESS OF THE AIR POLLUTION FEE POLICY

The unfairness of the APF policy can be judged from two aspects: fee collection and spending. In this article, fairness is defined as the equality of fee collection and spending per unit of air pollutant emissions and/or per unit of ambient air quality. Article 10 of the 1992 Taiwan Clean Air Act Amendment (CAAA) clearly indicates that APF must be levied according to emission rate and Article 14 of Taiwan's 1992 CAAA by-laws further specifies that APF should be used for air pollution control only. Unfortunately, the current APF levy system is based on fuel consumption rates rather than exact individual pollutant emission rates. For industries, the charges are NT$150 per *kl* of fuel oil and NT$170 per ton of coal. For vehicles, the charges are NT$0.2 per *l* of unleaded gasoline, NT$0.4 per *l* of leaded gasoline, and NT$0.2 per *l* of diesel. In addition, NT$65 per *l* is charged for CFC consumption. It is estimated that a total of NT$6.9 billion can be collected in one year with 43% from mobile sources and 57% from stationary sources. Apparently, such a fee collection method is more like an energy tax or a green tax rather than pollution-based emission fees because there are no similarities in the emissions of these fuel sources except CO_2, which is not treated as an urban air pollutant. Moreover, the emission rates are also different for the same fuel used by different vehicles and manufactured from different processes. Legally speaking, the current APF policy has violated the authority empowered by the 1992 CAAA. According to Article 10 of the 1992 Taiwan CAAA, the Taiwan EPA is not allowed to collect pollution fees in such a way. As a matter of fact, it is currently being challenged by several legislators and still waiting for constitutional review in the Supreme Court in Taiwan. In addition to legal problems, several technical problems in the APF policy result in unfairness to society and ineffective control of air pollution in Taiwan. We will address these issues in detail in the following sections.

The APF policy is unfair because it does not take into consideration the regional differences in the air quality in Taiwan. As we pointed out before, the air quality in Zones VII and VIII has met all of the requirements of the NAAQS for the past two years. In comparison to the NAAQS, the air quality in these two regions is only 60% of the limit for PM10, 3-8% of the limit for SO_2, 90% and 2% of the limit for NO_2. Apparently, there seems to be no basis for further air pollution control in these two areas unless the government specifies air quality goals other than the NAAQS. Therefore, it is unfair for residents and industries to pay APF in these two areas. Judging from Article 14 of the 1992 Taiwan CAAA by-laws, it is illegal even to collect APF in these two areas. It is illegal to collect APF in areas where no controls are needed. It is even more unfair for residents living in the areas surrounding Zone IV and Station 47 because they are receivers rather than contributors of air pollutants. Instead of paying APF, they ought to be compensated by people living in the communities upwind. Even for residents who live in regions violating the NAAQS, it is unfair for them to pay similar rates of APF because the severity of air pollution is widely different among regions. For example, the air quality in Zone VI is the worst among the 8 air basins. Both PM10 and O_3 problems in this air basin is about 2-3 times worse than the other air basins in the western region of Taiwan. Undoubtedly, a flat rate charged to all emitters in all regions will cause the market-based economic incentive tool to lose flexibility in achieving air quality goals. The current APF policy will place on unfair burden on industries and residents in areas with less severe air quality problems. The improvement of air quality in Zone VI will also be slowed down by the APF's inflexible fees.

THE INEFFICIENCY OF THE AIR POLLUTION FEE POLICY

The APF policy is inefficient because it does not take into consideration the seasonal differences in the air quality in Taiwan. In the summer from June to August, the air quality is the best in almost all air basins except Zone I. The air quality is either better or slightly higher than the NAAQS for most criteria air pollutants during this season because air pollution seems to be greatly diluted by meteorological conditions. By charging industries and individuals the same APF for all four seasons, the opportunity for more economic activity in the summer for some regions will be missed. Again, the advantage of control flexibility to combat air pollution is limited by the current APF policy.

The APF policy, furthermore, is inefficient because it does not take into consideration the differences between individual pollutants in the deterioration of air quality in Taiwan. For Station 25, APF should be based on SO_2; for Zones I to VI, APF should be based on PM10; for Zones I, II, III and VI, APF should be based on ozone precursors, such as hydrocarbons (HCs) and nitrogen oxides (NO_x). By not charging APF for individual pollutants, we not only miss targeting the problem of improving air quality but also put on unfair burden on certain industrial sectors and social classes. With the current APF policy, Taiwan's economic competitiveness could be dampened because some industries with limited contributions to air pollution problems are levied with unnecessary fees. Moreover, the policy may misdirect environmental professionals in air pollution controls. However, it is worthwhile to note that our arguments for the inefficiency of the current APF policy are only true if the transaction costs of implementing fee collection programs for considering seasonal and pollutant factors are the same as the current APF.

THE INEFFECTIVENESS OF THE APF POLICY

The effectiveness of the APF policy can be evaluated from two perspectives: market-based incentive and air quality improvement. Ineffectiveness is defined as the inability to change the current practices of the polluter and/or to improve air quality to meet the NAAQS. Since the Taiwan EPA proclaimed that the current APF policy is a market-based incentive policy, we must first review its effectiveness from this perspective. The APF policy is ineffective because the current pollution fees charged are not high enough to decrease pollution caused by industries or individuals. As recommended by the industrial members of the OECD in 1972, a "polluter pays" policy would make sure that polluters carry the full costs of their actions [5]. Unfortunately, the fees levied on individual emitters in the current APF policy do not reflect the full cost of air pollution because they are not based on total damage or total control cost. Until now, there are simply not enough data to perform such complicated estimations of air pollution in Taiwan. Not only are the estimations of exact pollution costs not available but also the price ratios of pollution fees charged to various emission sources are incorrect in the current policy. The APF does not truly reflect differences in emission rates from individual emitters. As reported by Chan *et al.*, significant differences in the emission of THC, CO, NO_x, and VOCs are found among various vehicles in Taiwan. THC emission factors are 1.36 g/km for non-catalyst cars, 0.13 g/km for catalyst cars, 3.77 g/km for 2-stroke motorcycles, and 0.64 g/km for 4-stroke motorcycles. CO emission factors are 7.28 g/km for non-catalyst cars, 0.87 g/km for catalyst cars, 7.47 g/km for 2-stroke motorcycles, and 3.99 g/km for 4-stroke motorcycles. NO_x emission factors are 1.88 g/km for non-catalyst cars, 0.11 g/km for catalyst cars, 0.007 g/km for 2-stroke motorcycles, and 0.19 g/km for 4-stroke motorcycles [6]. Compared with catalyst cars, 2-stroke motorcycles and non-catalyst cars are found to emit 12 times as much THC and CO for every kilometer driven. For NO_x, non-catalyst cars have the highest emissions, while 2-stroke motorcycles have the lowest emissions. Under the current APF policy, motorcycles and non-catalyst cars are not fully charges for their emissions. Very likely, the economic incentive may not be strong enough for people to switch from dirty vehicles to clean ones.

The APF policy is ineffective because its current funding strategies are unrelated to air pollution control in Taiwan. According to the Taiwan EPA, the NT$6.9 billion collected in the first year will be divided into 9 portions, which will subsidize local control strategies (37%), stationary sources control (9%), mobile sources control (12%), international cooperation (1%), schoolchildren's health checks (4.4%), "eco-parks" (29%), research and planning (1.6%), operation and maintenance of air monitoring networks (0.9%), and public education and administration (4.7%). However, mobile and stationary sources together account for 60-90% of total emissions in most areas in Taiwan. Thus, the proportion of money spent on controlling these two pollution sources is too small in comparison to their emissions. The results from further examination of APF funding programs in the following sections also indicate that APF funds have been spent misappropriately.

1. Useless "eco-parks"

The EPA has proclaimed without sound scientific evidence that the planned 134.3186 acres of so-called "eco-parks" will assimilate about 488.94 tons of CO, 2,337.26-3,967 tons of SO_2 and 2,579-7,307 tons of suspended particulates per year in Taiwan. It is not clear that air pollution can be reduced by the kinds of plants and mechanisms in these "eco-parks." Nevertheless, the EPA has estimated that pollution can be decreased to 10 kg. Even assuming that such an estimation may be true, assimilation by "eco-parks" accounts for only 0.002% of total CO emissions, 0.40-0.68% of total SO_x emissions, and 1.28% of total suspended particulate emissions. Obviously, it is illogical to spend so much money on so little gain in air pollution improvements. This is not consistent with the usefulness of APF policy, which is supposed to be an efficient and cost-effective market-based tool. Additionally, a significant regional difference in the distributions of areas of "eco-parks" is designed by the Taiwan EPA. For example, there are 29 acres in Taitung of Zone VII and 1.04 acres in Kaohsiung of Zone VI. Ironically, the best air quality is in Zone VII while the worst is in Zone VI. Apparently, no consistency in "eco-park" planning can be found in the current APF policy even if these "eco-parks" have the effects proclaimed by the Taiwan EPA.

2. Chaos in subsidies for local control strategies

This policy was originally designed with good intentions to give 26 local governments more freedom in setting up their own control strategies according to local need. The premise of this policy is that local governments know very well their pollution problems and can propose good solutions. Unfortunately, this is not true in most cases. Most local environmental protection bureaus simply do not have the technical staff necessary to monitor air quality, not to mention to propose air quality management plans. As a result, this policy has put a lot of physical and mental strain on employees in the local environmental protection bureaus. Most projects submitted to the EPA have similar strategies and are written by a few consulting companies. Moreover, most proposals for pollution reduction are based mainly on administrative measures rather than engineering control. One common drawback of these proposals is the lack of quantitative analysis for program evaluation, making it very difficult to audit the merits of pollution control for individual projects. It is really doubtful how administrative measures will cut down air pollution when bureaucrats are already being overwhelmed by routine paper work. The amount of money which has already been awarded to various local governments accounts for about 25% of the subsidies. It is also doubtful whether county-based strategies can be effective for air pollution control in Taiwan. As the air quality data indicate, PM10 and O_3 pollution problems are basin-wide rather than county-wide. Therefore, more effective control strategies for these two problems should be directed toward air basins.

3. Inauthentic health checks for schoolchildren

This project was designed to collect basic health data from all schoolchildren in primary schools and junior high schools for three years. Except for establishing population norms of health index, the objectives of this project are not clearly stated. In the first year, about NT$300 millions will be spent on questionnaires for 1.19 million students and lung function tests for 0.2 million students in junior high schools. Although this project is funded as a health examination program, it is not a genuine health check program for children because its health evaluation tool is largely limited to a questionnaire and to a lesser proportion, the lung function test. It is well known that health history and a physical examination by pediatricians or general practitioners are the minimal requirements for an authentic child's health examination. According to the US Preventive Services Task Force, the screening items of health examinations for children aged 13-18 include taking down health history, physical exam, and laboratory/diagnostic procedures [7]. Therefore, this project is more like an epidemiological study on child respiratory symptoms and lung functions than a standardized health check. This study will waste tremendous manpower and money on surveying 1.19 million subjects to get information which can be more efficiently obtained by sampling representative subjects. In practice, the data quality can also be better assured by smaller samples. Furthermore, this project does not meet the definition of public health surveillance specified by the US Center for Disease Control (CDC) [8]. The definition states that public health surveillance is the ongoing, systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with timely dissemination of these data to those who need to know. The final link of the surveillance chain is the application of these data to prevention and control. Apparently, it is hard to find any relation between this project and a standard health surveillance program. It becomes pointless to continue such a project unless the collected data can be used to estimate the cost of damage associated with air pollution or to compensate the victims of air pollution.

ALTERNATIVE POLICIES FOR AIR POLLUTION CONTROL

The three most significant urban air pollutants problems in Taiwan are PM10, O_3, and air toxics. Effective control strategies for these air pollutants depend on the development of a database, which includes scientifically reliable ambient measurements, meteorological monitoring, and emissions inventory of all stationary, mobile, and biogenic sources that impact individual air basins. Quantitative estimation of control strategy effectiveness also depends on robust air quality models which can accurately estimate the relationship between emissions inventories and observed pollutant concentrations. However, our understanding of these issues is regrettably limited in Taiwan. A comprehensive ambient air quality monitoring network has been established and operated island-wide for only two years. Tail-pipe emissions tests from mobile sources and stack emissions tests for stationary sources are only sporadically performed. The application of commonly used air quality models, such as dispersion, receptor, and air-shed models, are usually found unsuitable in Taiwan because of the lack of validation for model parameters. With such uncertainties and limitations in mind, we will try to propose some alternative control strategies based on the best available scientific information.

Chan *et al.* reported that the ambient air concentrations of 8 VOCs, CO, NO_x, and THC in Taipei in Zone I can be apportioned to 7 different mobile sources by an empirical receptor model, which is based on Markov Chain Monte Carlo simulation [9]. For 8 VOCs, non-catalyst passenger cars (53-61%; 90.0-220.3 $\mu g/m^3$) and motorcycles (6-31%; 12.0-129.1 $\mu g/m^3$) are two major contributors. For NO_x, passenger cars (50-62%; 0.05-0.27 $\mu g/m^3$) and diesel cars (25-42%; 0.02-0.05 $\mu g/m^3$) are two major contributors. Motorcycles are the greatest contributors to CO (70-76%; 0.81-4.97 $\mu g/m^3$). For THC, gasoline vapor (17-58%; 0.35-0.85 $\mu g/m^3$) and 2-stroke motorcycles (25-53%; 0.17-1.39 $\mu g/m^3$) are two major contributors.

In order to reduce the long-term health risks associated with VOC exposure, such as from benzene, the emissions from non-catalyst passenger cars and motorcycles in metropolitan areas have to be cut down first. Two approaches for this type of reduction are the phase-out of non-catalyst cars and 2-stroke motorcycles and the phase-in of high quality gasoline with low benzene and aromatics. The emission reduction can be even greater by the introduction of alternative transportation or alternative fuels, such as efficient mass transits and bus services, electric cars, liquid propane gas cars, and compressed natural gas cars, in metropolitan areas. VOC can also be emitted from industrial processes in industrial areas, such as the air basin of Zone VI. Further improvements in air quality can be expected if industrial emission reduction strategies can also be applied simultaneously to this area. However, we cannot quantitatively estimate the amount of emission reduction by industrial controls as we do for mobile sources. More information is needed for scientifically sound judgment.

It is well-known that urban O_3 is formed by its two main precursors, NO_x and HC, through photochemical reactions. The Empirical Kinetic Modeling Approach (EKMA) model has been used by the U. S. EPA to determine ozone control strategies for urban areas in the U. S. By simulating an air mass as a box of air with predetermined combinations of initial HC and NO_x concentrations, the EKMA model generates ozone isopleths specific to particular urban sites as indicated in Fig. 2 [10]. In the EKMA model, urban ozone problems can be separated into HC-limited or NO_x-limited regions by specific HC/NO_x ratios. HC-limited regions are where HC/NO_x ratios are smaller than 8:1, and NO_x-limited regions are where HC/NO_x ratios are greater than 8:1. The monitoring data of Taiwan show that HC/NO_x ratios are all greater than 8:1. For example, the ratios are 16:1 in Zone I and 14:1 in Zone VI. This implies that we should lower ozone concentrations by reducing NO_x emissions in Zones I and VI. If only HC emissions are reduced in Zones I and VI, there is a possibility of increasing the ozone problem in these two regions. In order to reduce ozone concentrations in Zone I, it seems to be a sensible control strategy to cut down NO_x emissions from passenger cars and diesel vehicles. Therefore, existing diesel-powered trucks and buses should be replaced by new vehicles with alternative fuels. Strict regulations on NO_x emissions should also be enforced for existing and new passenger cars. Ways of reducing the traffic volume in the Taipei metropolitan are encouraged. In order to reduce ozone concentrations in Zone VI, we need to control mobile as well as stationary sources because they are major emitters of NO_x in this region. However, we cannot quantitatively estimate the amount of emission reduction by industrial controls as we do for mobile sources because there is simply not enough information to perform such calculations.

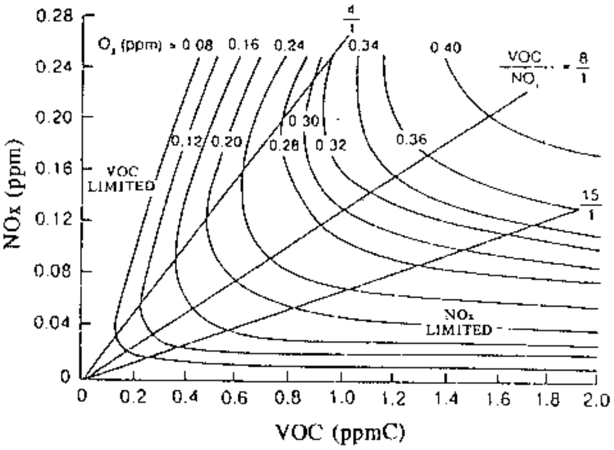

Fig. 2. Typical ozone isopleths used in EPA's EKMA. The NO_x limited region is typical of locations downwind of urban and suburban areas, whereas the VOC-limited region is typical of highly-polluted urban areas (Source: Adapted from Dodge, 1977).

Although PM10 pollution is the most serious air pollution problem in Taiwan, we have very little emission data for air quality modeling. Receptor models have generally failed to produce reliable estimates of source apportionment because the emission factors of various sources are not well-characterized in Taiwan. However, mobile, industrial, and fugitive sources have been speculated as being the three major PM10 emission sources in Taiwan. Since their quantitative contributions cannot be determined directly from well-developed air quality models, we have tried various statistical models to indirectly estimate achievable attainment goals for PM10 in different air basins from the fuel consumption, industrial density, and population density in each region. Unfortunately, the results show that ambient PM10 concentrations are not significantly related to these emission surrogates of PM10. Therefore, we can not formulate effective PM10 control strategies based on such limited emission inventory data. In order to develop PM10 control strategies, which can be quantitatively evaluated, there is a need to establish PM10 emission characteristics from all major domestic sources.

The alternative control strategies which we have proposed in the above sections are solely based on the science of air pollution. Based on the best available information, we can only point to the correct air pollution problems and their emission sources in this article. Will our alternatives be more effective in terms of economic analysis? Apparently, we are not in a position to claim so because we do not propose detailed control plans in any of our alternatives.

Moreover, we do not take into consideration the policy's transaction costs, such as the costs of administration, enforcement, and program auditing. In general, transaction costs rise as a policy's sophistication increases.

CONCLUSIONS

This article's underlying concept is environmental equity and cost effectiveness. Air pollution is a relatively serious environmental problem in Taiwan. Some regions of Taiwan are more seriously afflicted than others. It is morally wrong to charge air pollution fees to pollution victims who should be compensated. A public policy without justice will not be supported in a democratic society. The direct and indirect costs of air pollution control are enormously high. Some controls may be more effective than others in one region. The most efficient economic tool should be flexible enough to reflect such differences in the effectiveness of controls. Otherwise, the controls will be less cost effective. As a newly developed country, Taiwan cannot afford to have an air pollution fee policy that costs the public and industries vast amounts of money and achieves little in air quality improvement. Judging from this perspective, the APF policy is destined to be a failed environmental policy.

In this paper, two alternative approaches of air pollution control in Taiwan have been examined: (i) Improvements in ozone pollution problems in the metropolitan areas can be quantitatively estimated by the reduction in NO_x emissions from motor vehicles, and (ii) improvements in PM10 pollution problems can be achieved by simultaneously controlling mobile, industrial, and fugitive emission sources without sound quantitative estimation. More scientifically reliable data are needed in order to formulate control policies for ozone and PM10 in industrial areas in Taiwan because reliable emissions inventory of stationary, mobile, fugitive, and biogenic sources are not available in these areas. It is, therefore, highly recommended that correct PM10 emissions data should be established in Taiwan. Judging from this perspective, the APF policy is undoubtedly a pre-mature environmental policy, which is better to totally stop or largely revise.

The contents of this paper are by no means comprehensive, which is not our intention. We are aware that there are also several other studies and reports on air pollution problems in Taiwan by various distinguished researchers. We did not cite these studies in this paper because they do not fit the framework of our discussion. This does not necessarily mean that they are not important. We welcome any further information added to our discussion in terms of APF fairness and effectiveness. We do not propose alternative policies for the collection of the pollution fee because that is not our main interest in this paper. However, the discussion of this paper does provide some clues for improved methods of air pollution fee collection in Taiwan. We do not fully explore the pros and cons of environmental policies between market-based incentives and administrative controls because it is beyond the scope of this article. Theoretical discussions about comparative advantages between these two strategies have been reported by Weitzman [11]. Such an issue is so important that another article, favorably done by environmental economists, dealing with the implication associated with APF policy is highly recommended. Additionally, it will be better if the APF policy can be based on either exposure assessments or risk assessments of various air pollutants from a public health perspective. Therefore, we strongly recommend more research on these two issues in order to provide more information for a better APF policy.

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出售藍天：空氣污染防制費的一些省思

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摘　要

目前台灣正運用空氣污染防制費政策來降低都市空氣污染問題。本篇文章由空氣品質狀況、空氣污染防制費徵收方法和由其經費支助之主要污染防制計畫之觀點，來探討空氣污染費政策的公平性和有效性。我們發現由於空污費的徵收方法未能考慮空氣品質區域性和季節性的差異，因此目前的空氣污染防制費政策為一不公平的政策；此外，空污費的徵收不能反映各種來源排放量的差異，且其經費使用計畫並不能針對台灣空氣污染惡化的原因來運用，所以利用目前的空氣污染防制費來降低空氣污染問題是無效的。整篇文章所透露的訊息是現行的空氣污染防制費政策應做全面性的修正，我們同時根據較佳的空氣污染科學知識為基礎，提出控制台灣空氣污染的替代方案。