



## Particulate Matter Pollution: A Continuing Problem in Tirana's Air Quality: Status and Trends

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Air quality monitoring in Tirana city in the last two decades has indicated that air pollution from particulate matter is the main problem of the urban air quality. This pollution is especially high near areas with a great traffic density, thus showing that road traffic remains the main source of air particulate matter emissions. The measurements carried out for 15 months (April 2008-June 2009) regarding the total suspended particulate (TSP) and particulate matter less than 10 microns (PM<sub>10</sub>) in one of the main cross-roads of Tirana city resulted in values that continuously exceed the national norms for these air pollutants. Comparison of results from this study with PM<sub>10</sub> levels in a former study carried out in the period 1997-1998 in the same monitoring point evidences a reduction of PM<sub>10</sub> concentrations by 70 µg/m<sup>3</sup>, which could be explained by improvements made in infrastructure and measures taken regarding the controlling of pollution sources.

**Key Words:** Tirana air quality, Total suspended particulate, Particulate matter, Pollution, Tirana, Albania.

### INTRODUCTION

Tirana is the capital of Albania and is located in the central part of the country. In 2005, in the urban area of Tirana lived *ca.* 700,000 inhabitants, but most likely the population is increased thenceforth. The area is dominated by a mediterranean climate with dry and hot summers. The main wind direction during summer is NW and during winter SE. The wind velocity is low during almost all year. From two decades, Tirana city is being exposed to high levels of particulate matter and the population living here is suffering the consequences of this pollution. While the concentrations of other principal pollutants NO<sub>x</sub>, SO<sub>2</sub> and O<sub>3</sub> generally have been within the allowed norms, the levels of total suspended particulate in Tirana's air are noticeably higher than the approved national and international norms<sup>1-4</sup>. The high concentrations of particulate matter (PM) in the air classify Tirana as one of the highest particulate-contaminated capital in Europe<sup>5,6</sup> and at the same time as the city with the highest air pollution in Albania<sup>7,8</sup>.

The combined factors of increase in the road traffic density and the lack of significant improvements in road infrastructure seemed to be the main contributor to the high levels of particulate matter pollution in urban air of Tirana city. Besides the immense growth of traffic and the inefficient traffic management, the old age and the poor technical conditions of most vehicles have also played a significant role in increasing of pollutant emissions<sup>5,6,9</sup>.

Several studies have demonstrated the negative effect of particulate matter on human health and have confirmed an association between the elevated levels of particulate air pollution and decline in lung function or increase in various respiratory diseases. Especially PM<sub>10</sub> (small particles less than 10 µm) is known to cause a wide range of negative effects on the respiratory and cardiovascular systems, asthma and mortality<sup>10-12</sup>. These health effects deal with the fact that the small particles penetrate the human respiratory system and can reach the lung alveoli causing serious damage to health. Scientific evidence suggests that long term exposure to fine particles could lead to a reduction of life expectancy. Children, elderly people and individuals with impaired lung or heart function are especially susceptible to the adverse health effects associated with inhalation of airborne particulate matter<sup>13,14</sup>.

Assessment of urban air pollution from particulate matter in Tirana city has been the object of some studies carried out in Albania during the recent years. They have contributed in creating the necessary scientific basis, which helps in the evaluation of the pollution situation, its management and control. The study, which is being presented in this article was carried out in the period April 2008- June 2009 and it is based on the measurements of the total suspended particulate and PM<sub>10</sub> concentrations in one of the main cross-roads of Tirana, the square Mustafa Qemal Atatürk, which constitutes one of the areas with the highest air pollution. The goal was to evaluate

TABLE-1  
SUMMARY STATISTICS FOR TSP CONCENTRATIONS ( $\mu\text{g}/\text{m}^3$ ) DURING APRIL 2008  
-JUNE 2009 IN THE CROSSROAD OF THE SQUARE MUSTAFA QEMAL ATATURK

| Parameters         | All samples | Season |        |        |        | TSP national limit           |                              |
|--------------------|-------------|--------|--------|--------|--------|------------------------------|------------------------------|
|                    |             | Spring | Summer | Autumn | Winter |                              |                              |
| Number of samples  | 240.00      | 80.00  | 64.00  | 48.00  | 48.00  | Annual                       |                              |
| Arithmetic mean    | 218.03      | 219.95 | 229.97 | 203.0  | 213.92 | Average:                     |                              |
| Standard deviation | 60.86       | 72.11  | 54.37  | 30.84  | 68.81  | 140 $\mu\text{g}/\text{m}^3$ |                              |
| Percentiles        | 10 %        | 143.05 | 133.89 | 161.53 | 164.44 | 139.44                       | 24 h average:                |
|                    | 90 %        | 303.19 | 322.91 | 306.11 | 245.27 | 290.14                       | 250 $\mu\text{g}/\text{m}^3$ |

TABLE-2  
SUMMARY STATISTICS FOR PM<sub>10</sub> CONCENTRATIONS ( $\mu\text{g}/\text{m}^3$ ) DURING APRIL 2008-  
JUNE 2009 IN THE CROSSROAD OF THE SQUARE MUSTAFA QEMAL ATATURK

| Parameters         | All samples | Season |        |        |         | PM <sub>10</sub> national limit |                              |
|--------------------|-------------|--------|--------|--------|---------|---------------------------------|------------------------------|
|                    |             | Spring | Summer | Autumn | Winter  |                                 |                              |
| Number of samples  | 240.00      | 80.00  | 64.00  | 48.00  | 48.00   | Annual                          |                              |
| Arithmetic mean    | 116.95      | 119.86 | 122.34 | 106.78 | 115.1   | Average:                        |                              |
| Standard deviation | 32.07       | 38.00  | 19.26  | 15.52  | 35.37   | 60 $\mu\text{g}/\text{m}^3$     |                              |
| Percentiles        | 10 %        | 79.17  | 71.94  | 86.80  | 86.11   | 75.00                           | 24 h average:                |
|                    | 90 %        | 163.88 | 173.75 | 159.16 | 126,804 | 152.92                          | 150 $\mu\text{g}/\text{m}^3$ |

the variation of particulate matter concentrations during different seasons. On the other hand, comparison of results received in this research with the PM<sub>10</sub> concentrations received from another research carried out 10 years ago in the same area in Tirana allows for definitions of trends regarding the situation of PM<sub>10</sub> air pollution during the last 10 years.

### EXPERIMENTAL

Total suspended particulate and PM<sub>10</sub> sampling was conducted in the crossroad of the square Mustafa Qemal Ataturk, which is situated in the western part of the city centre, in a very high traffic density zone. 24 h particle samples were collected every 2 days during the period of April 2008 to June 2009, corresponding to 16 TSP (total suspended particulate) and 16 PM<sub>10</sub> samples for each month.

The determination of the TSP and PM<sub>10</sub> was made by the gravimetric method according respectively to the ISO 7708: 1995 -air quality-particle size fraction definitions for health-related sampling and EN 12341:1998 - standard determination of the PM<sub>10</sub> fraction of suspended particulate. Sampling of TSP was performed using low-volume air samplers through a filter vacuum pump with an average flow rate of 5 L/min. Sampling of PM<sub>10</sub> was performed using a low-volume air sampler equipped with a specific sampling head for particles with a diameter less or equal of 10  $\mu\text{m}$ . The air passed through the filter (47 mm diameter) with the pores sizes of 0.8 mm. Particle mass was measured by weighing the filters before and after sampling. The difference in weight of filters ( $\mu\text{g}$ ) divided by the volume of air ( $\text{m}^3$ ) gives the TSP and PM<sub>10</sub> content in  $\mu\text{g}/\text{m}^3$ .

An excel file was used to build the data base and minitab software was used to perform the statistical analysis. To study the effect of seasons and the effect of periods of time on the variables PM<sub>10</sub> and TSP, it was tested the equality of means performing the one-way ANOVA.

### RESULTS AND DISCUSSION

Tables 1 and 2 showed the overall statistics of the measured levels respectively for TSP and PM<sub>10</sub>, whereas Fig. 1

presents graphically the 24 h-average values TSP and PM<sub>10</sub> concentrations.

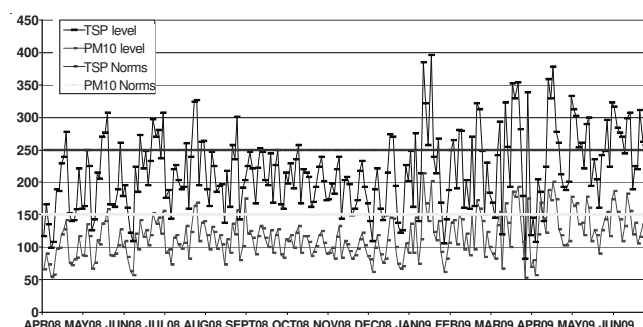


Fig. 1. 24 h average of TSP and PM<sub>10</sub> concentrations

As it is seen from the information presented in the above Tables and Figure, the concentrations of TSP and PM<sub>10</sub> during the period April 2008-June 2009 vary widely, which is expressed in the relatively high values of standard deviations. In the samples taken, PM<sub>10</sub> constitutes about 0.54 of TSP concentration. The correlation between the values of TSP and PM<sub>10</sub> is high and with a correlation coefficient of 0.94.

The results of this research show that the levels of particulate matter in this area of the Albanian capital are very high. They exceed considerably the TSP and PM<sub>10</sub> limit levels defined by the national and international standards. Thus the annual average for TSP and PM<sub>10</sub> is respectively 1.6 and 1.9 times higher than the limit level defined by the national standard of air quality for these air pollutants. The exceedance of norms is much higher if these concentrations would be compared with the European Union directives, which define a limit value for PM<sub>10</sub> = 40  $\mu\text{g}/\text{m}^3$ . Compared to this limit the annual average of the measured values for PM<sub>10</sub> is about 3 times higher. Moreover, from Fig. 2, where there are presented the monthly average values of TSP and PM<sub>10</sub>, it is noticed clearly that the air content of particulate matter is high during all the months when this study was carried out and they continuously overcome the long-term norms for these two air pollutants.

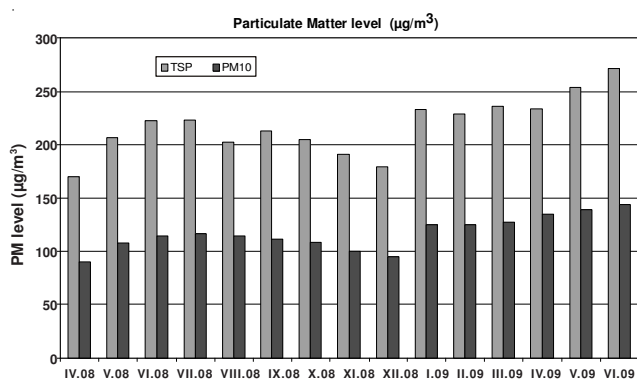


Fig. 2. Monthly means of TSP and PM<sub>10</sub> concentrations

The violation of standards is noticeable in a considerable number also for the short-term norms (24 h average limits). In the 240 measurements carried out in this area for the air concentrations of TSP, 66 of them or 27.5 % exceeded the limit value of 250 µg/m<sup>3</sup> defined by the Albanian standard. In a similar way, 36 out of 240 measurements carried out for the PM<sub>10</sub>, or 15 % of them, resulted higher than 150 µg/m<sup>3</sup>, defined as a daily limit value by the Albanian standard of air quality. On the other hand, if comparison would be made with the EU air quality directive, which since 2005 defines 50 µg/m<sup>3</sup> as PM<sub>10</sub> daily limit value, it results that none of the measured values does comply with this limit.

By comparing the average values of PM<sub>10</sub> in the urban air of Tirana with the average levels reported for some of the capitals of the world (Table-3), it is clearly seen that the PM<sub>10</sub> content in the urban air of Tirana is a few times higher than the PM<sub>10</sub> content in the European capitals but it is lower than the reported levels for Delhi and Cairo<sup>15</sup>. These data confirm again the conclusions of former studies, which classify Tirana as one of the European cities with the highest particulate matter pollution<sup>5-7,9</sup>.

From the data presented and the discussions above it is clear that the particulate matter pollution constitutes a serious problem for the urban air quality of Tirana and that its inhabitants continue to be exposed to extremely high levels of TSP and PM<sub>10</sub>, which are continuously higher than the national and international norms.

It is worth mentioning that in Albania there is a lack of real epidemiological studies regarding the effects of particulate matter pollution on public health. Nevertheless, keeping in

mind the high particulate matter levels in Tirana's air and the results of several epidemiological studies carried out in other countries regarding associations between concentrations of particulate matter and adverse effects on human health it could be safely thought that the health of Tirana's citizens is seriously threatened by the high particulate matter pollution. According to these studies the effects on mortality, respiratory and cardiovascular hospital admission and other health variables have been observed at levels well below 100 µg/m<sup>3</sup>, expressed as a daily average PM<sub>10</sub> concentration. Some studies have suggested that long-term exposure to particulate matter is associated with reduced survival and reduction of life expectancy in the order of 1-2 years<sup>13</sup>.

#### Seasonal variation of particulate matter concentration:

To test the equality of means for PM<sub>10</sub> and TSP, it was used ANOVA procedure. The one-way output contains these *t*-test *p*-values, *P* = 0.127 for TSP and *P* = 0.058 for PM<sub>10</sub>, indicating that in the four seasons there is no significant distinction between the mean of the TSP and also there is no significant distinction between the mean of PM<sub>10</sub>.

However, if the data are studied grouped according to two periods: the winter period (October-March) and summer period (April-September), the differences in the average values calculated for the TSP and PM<sub>10</sub> are more than noticeable. The concentrations of the two pollutants are higher in the summer period, which is expected if it is taken into consideration that this time period in Tirana city is dry and it is characterized by high temperatures. As it is seen from Table-4, a significant difference in the value of TSP and PM<sub>10</sub>, was observed. The *t*-test *p*-value respectively of 0.047 and 0.017 indicates the influence of the above period in these air pollutants.

Distinction between the periods appears not only on the average levels of TSP and PM<sub>10</sub>, but at the same time in the number of days for, which the measured values of pollutants exceed the daily limits defined by the Albanian standard of air quality for these two pollutants (Fig. 3). In the summer period the percentage of days on which these limits are exceeded is twice as much as the ones in the winter period.

**Study of the situation of particulate matter air pollution in time and its trends:** If the values of concentrations measured for PM<sub>10</sub> during the period April 2008-June 2009 in the crossroad of the square Mustafa Qemal Atatürk are to be compared with the values of PM<sub>10</sub> received from a similar study

TABLE-3  
AVERAGE LEVELS OF PM<sub>10</sub> IN SOME WORLD CAPITALS (YEAR 2004)<sup>15</sup>

| City                                  | Rome | Athens | Berlin | Vienna | Zagreb | Paris | London | Prague | Sofia | Delhi | Cairo |
|---------------------------------------|------|--------|--------|--------|--------|-------|--------|--------|-------|-------|-------|
| PM <sub>10</sub> (µg/m <sup>3</sup> ) | 29   | 43     | 22     | 41     | 33     | 11    | 21     | 23     | 61    | 150   | 169   |

TABLE-4  
TOTAL SUSPENDED PARTICULATE AND PM<sub>10</sub> AVERAGE LEVELS IN SUMMER AND WINTER PERIOD, ONE-WAY ANOVA RESULTS FOR TWO PERIODS

|                  |                    | Summer | Winter | One-way ANOVA       |       |      |
|------------------|--------------------|--------|--------|---------------------|-------|------|
|                  |                    |        |        | F <sub>(0.95)</sub> | P     | d.f. |
| TSP              | No of samples      | 144.00 | 96.00  | 4.00                | 0.047 | 239  |
|                  | Arithmetic mean    | 224.40 | 208.46 |                     |       |      |
|                  | Standard deviation | 64.81  | 53.32  |                     |       |      |
| PM <sub>10</sub> | No of samples      | 144.00 | 96.00  | 5.74                | 0.017 | 239  |
|                  | Arithmetic mean    | 120.96 | 110.94 |                     |       |      |
|                  | Standard deviation | 34.30  | 27.49  |                     |       |      |

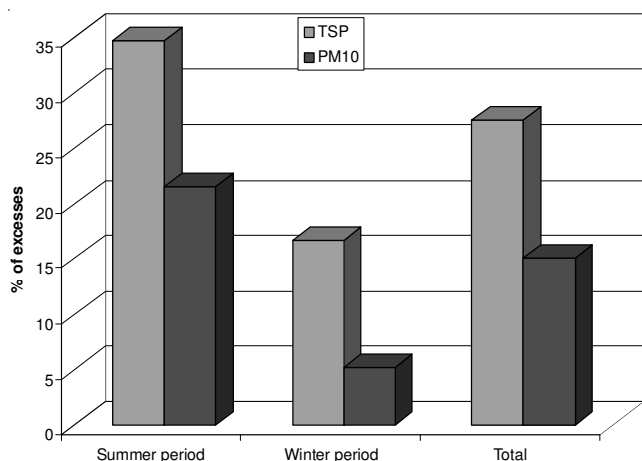


Fig. 3. Albanian standard TSP and PM<sub>10</sub> limit exceedances (%) during April 2008-June 2009

carried out in the same area, during the period 1997-1998, it is noticed as below mentioned:

The levels of PM<sub>10</sub> in the air of this area of Tirana continue to be above the limit levels defined by the national standard of air quality, as well as above the air quality standards applicable to European Union countries. The high levels of particulate matter seemingly have originated from the heavy road traffic in this important crossroad of Tirana. Other factors that impact the air quality are: the majority of vehicles that circulate in the roads of the Albanian capital in general are very old diesel cars, which run on not so good diesel quality. These two factors combined make it even more clear the negative effect that they have on the increase of particulate matter air concentrations.

Although the levels of PM<sub>10</sub> in this area remain high and result above the norms, compared to the levels of PM<sub>10</sub> measured 10 years ago they are quite lower. For comparison, the average concentration of PM<sub>10</sub> in the period 1997-1998 has resulted 196.63  $\mu\text{g}/\text{m}^3$ , compared to 116.95  $\mu\text{g}/\text{m}^3$ , which is the average concentration of PM<sub>10</sub> in the samples studied in the period April 2008-June 2009 (Fig. 4). Thus, after 10 years there is noticed a decrease of 70  $\mu\text{g}/\text{m}^3$  or 40 % of the concentration of PM<sub>10</sub> measured in this area of the Albanian capital. The difference in the value of PM<sub>10</sub>, was observed in these two different periods of time. Performing ANOVA the one-way output contains  $F = 150.87$  with a  $P = 0.000$ . These values indicate the influence of the period of time in this air pollutant. The improvement of the situation regarding particulate matter pollution in the time period 2008-2009 compared to the time period 1997-1998 is supported also by comparing the daily concentrations of PM<sub>10</sub> measured in these two time periods. In the entirety of the measurements carried out for the PM<sub>10</sub> concentrations during the time period 1997-1998, 75 % of them exceeded the limit value of 150  $\mu\text{g}/\text{m}^3$  of the Albanian standard, while in the time period 2008-2009 only 15 % of daily averages measured exceeded this limit.

The reasons for this reduction in the particulate matter concentrations in the area under study could be given by examining the main sources of particulate matter in the urban air of Tirana and by analyzing the quantitative and qualitative

changes of these sources through the years. The studies carried out formerly regarding the air quality had shown that the main source of particulate matter in Tirana's air is road traffic. The old age of cars, their bad technical condition, the fact that the majority of them run on diesel, had impacted the increase of the contribution of road traffic on urban air pollution of Tirana. Moreover the bad fuel quality, the bad road infrastructure, the lack of green areas, the bad administration of urban waste and the increased construction activities had been evidenced as factors, which favoured the high particulate matter levels in the air of the Albanian capital. The measures undertaken in the last years regarding the control of these factors seem to have favoured the decrease of particulate matter concentrations, which nevertheless continues to remain high and beyond the allowed norms. Among these factors, as the most important ones there could be mentioned:

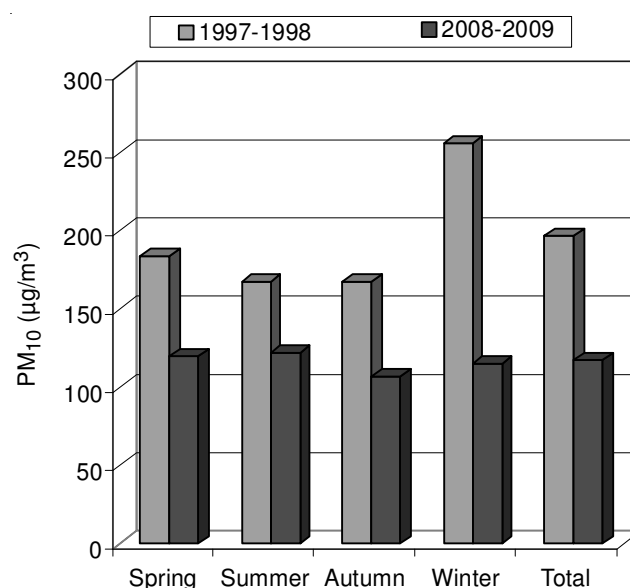


Fig. 4. PM<sub>10</sub> average levels during the time periods: 1997-1998 and 2008-2009

The measures undertaken regarding the infrastructure improvement, the road asphaltting and their maintenance, their periodic washing in the dry periods *etc.*

Measures undertaken regarding the improvements in the traffic fleet. The application since 2001 of a differentiated custom tax depending on their age, for the imported cars has promoted the increase of purchase of brand new cars and has discouraged the entrance of very old cars in the country. Also the application of the environment tax, which is based on the age of cars, their engine power and the type of fuel they run on, has positively impacted not only the purchase of new cars, but also the purchase of cars that run on gasoline. For example only in the period 2007-2008 there were purchased 6928 brand new cars<sup>16</sup>. The cars purchased in the period 2006-2009 were 9902 diesel cars and 9807 gasoline cars compared to 27928 diesel cars and 12949 gasoline cars purchased in the period 2000-2005<sup>17</sup>. The increase in the price of diesel and its approximation with the price of gasoline has been one of the other factors which promoted the increase in the trends of purchase of gasoline cars in Albania.

The improvements made in the solid urban waste administration, which includes their collection, transport and disposal is another important factor that has contributed in the lessening of particulate matter air concentrations in Tirana. The rehabilitation and extension of the only solid waste landfill in Tirana (which is located 7 km from the city center in the south-waste direction of Tirana city<sup>18</sup>) gave an end to the uncontrolled burning of waste, therefore it contributed to the decrease of air emissions of particulate matter and other harmful pollutants.

### Conclusion

The measurements carried out during a 15 month period regarding the TSP and PM<sub>10</sub> content in the air of one of the main crossroads of Tirana city show TSP and PM<sub>10</sub> levels, which are high and above the norms. The average concentrations of these pollutants resulted for TSP 218.03 ± 60.86 µg/m<sup>3</sup> and for PM<sub>10</sub> 116.15 ± 32.07 µg/m<sup>3</sup>, which are 1.5-2 times higher than the limit level defined by the national standard of air quality. The content of PM<sub>10</sub> is a few times higher than the reported levels for the main European capitals and 3 times higher than the annual average limit of 40 µg/m<sup>3</sup> defined by the European Union air quality directive.

Although there is not a significant distinction in the levels of particulate matter among the 4 seasons of the year, the higher levels correspond to the summer period (April-September). High temperatures and the lack of wet precipitation which are characteristic for the weather of this season seem to favour higher concentrations of particulate matter compared to the wet winter season (October-March).

The average levels of PM<sub>10</sub>, which resulted from this study, although above the norms, are about 40 % or 70 µg/m<sup>3</sup> lower than the ones measured in the same area during the years 1997-1998. This reduction of PM<sub>10</sub> levels could be explained by the effective measures undertaken after the year 2000 regarding the control of pollution sources and the factors that favour this pollution.

Among those, as the main ones could be mentioned the measures undertaken regarding the infrastructure improvement, road asphaltting and road maintenance in Tirana city, financial and custom policies for the promotion of purchase of brand new cars and of gasoline cars, rehabilitation of the urban solid waste landfill, *etc.*

Regardless the fact that compared to 10 years ago it is noticed a trend of decrease of particulate matter levels in the urban air of Tirana, the situation continues to remain very problematic. The citizens of the Albanian capital are daily exposed to very high levels of PM<sub>10</sub>. This is shown by the fact that out of 240 measures carried out in the frame of this research, the average of 24 h PM<sub>10</sub> concentrations never have resulted less

than 50 µg/m<sup>3</sup>, which is defined as the daily limit value by the European Union air quality directive.

High pollution levels suggest that it is necessary for the competent institutions to carry out epidemiological studies in order to show the real impact of air pollution on the health of the inhabitants of Tirana. Based on their findings it is compulsory to take further measures to control the air emissions of particulate matter and offer these inhabitants healthy air on daily basis.

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