ECOlogical supporting for traffic
Management in cOastal areas By using
an InteLligenT sYstem
01/01/2018 - 30/09/2019

Pollutants trend in Rijeka

University of Rijeka-Faculty of Medicine -

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DATA COLLECTION

Data collection started on March 1st 2018 and is still running. Pollution data collected until the end of the ECOMOBILITY project (30th September 2019) in Rijeka are presented and discussed in this report. Data were collected from five monitoring stations run by the regional Teaching Institute of Public Health, hosting at the same time the Environmental Health Department of the Faculty of Medicine - University of Rijeka. The selected stations[1] were three urban stations: Site 1- the Institute building, urban background, Site 2- new station, urban traffic located in the harbor area, Site 3- urban residential; Site 4 – industrial station, Site 5- residential in proximity of industrial and Site 6 – background, but in proximity (1 km away) of the regional municipal waste treatment plant. Site 7 (Bakar) was added for

Figure 1: Monitoring sites selected for tge implementation of the project

Comparative purposes. The parameters collected from the monitoring stations are reported in Table 1. Nitrogen bioxide (NO_2) and particulate matter below 10 µm (PM_{10}) were chosen as parameters monitored to create the supporting intelligent traffic management system, in common with the city of Venice). Thus the discussion will focus only on concentration data of NO_2 and PM_{10}.

[1]deliverable "Common and harmonized data collection", act 4.1

Table 1. List of parameters collected at monitoring stations.

Station	Type	Paramaters measured
1. Krešimirova st.(ZZJZ)	Urban background	SO_2, NO_2, $PM_{10,}$ T, RH, Wdir, Ws
2. Senj pear (Harbour)	traffic	NO_2, O_3, PM_{10}
3. Trogirska St. (Mlaka)	residential	SO_2, NO_2, O_3, CO
4. Urinj (Inžinjering)	Industrial	SO_2, H_2S,NO_2, NH_3, PM_{10}, CO, Bz
5. Paveki	residential	SO_2, H_2S,NO_2, O_3, PM_{10}, CO, Bz
6. Marišćina	background	H_2S, R-SH, NO_2, NH_3, PM_{10}, $PM_{2.5}$
7. Bakar	industrial	PM_{10}

NO_2: nitrogen dioxide; NH_3 – ammonia; PM_{10}:particulate matter <10 µm; $PM_{2.5}$:-particulate matter <2.5 µm; O_3: ozone; CO:carbon monioxide; SO_2 : sulphur dioxide; H_2S: hydrogen sulphide, RSH: mercaptans, Bz: benzene; T: temperature; RH: relative humidity; WPV: wind prevalent velocity; WPV: wind prevalent direction.

Hourly data were collected from all monitoring station for all analysed parameters. Software package ENVIMAN (Opsis, Sweden) was used for data elaboration.

Station 2 was purchased for this project. Due to long period for public procurement, the monitoring station was delivered only at the end of May, but due to some initial problems the currently available data analysed in this report are those for the period September 14th to December 3rd 2019.

GENERAL DISTRIBUTION OF POLLUTANTS

The average NO_2 concentration of the whole period (March 2018 to September 2019) at two urban sites (Krešimirova ul. and Trogirska ul.) are approx. the same, 25 and 23 µg/m^3 for hourly-NO_2, while in suburban and industrial sites these values are lower (and 12 and 9 µg/m^3, respectively). The average concentrations of daily PM_{10} in the same period are 24 and 23 µg/m^3 for urban (Krešimirova) and suburban (Marišćina) sites, while these values are lower in industrial site Urinj (15 µg/m^3) in the Rijeka suburban area, but not that much in another harbor area Bakar (20 µg/m^3) where bulk cargo is reloaded. approx. The highest measured concentrations were 140 µg/m^3 for 1-hour concentration at urban site Trogirska St (18/10/2018. at 6 PM) and 109 µg/m^3 for daily PM_{10} (16/4/2018 at 0 AM) at suburban site (Marišćina). On the other hand, maximum hourly PM_{10} concentration is measured at urban site Krešimirova st. (476 µg/m^3 on 29/08/2018. at 12 AM).

Distribution of NO_2 concentrations, including average value, minimum and maximum concentration of the given period at four monitoring stations are shown in Fig.2.

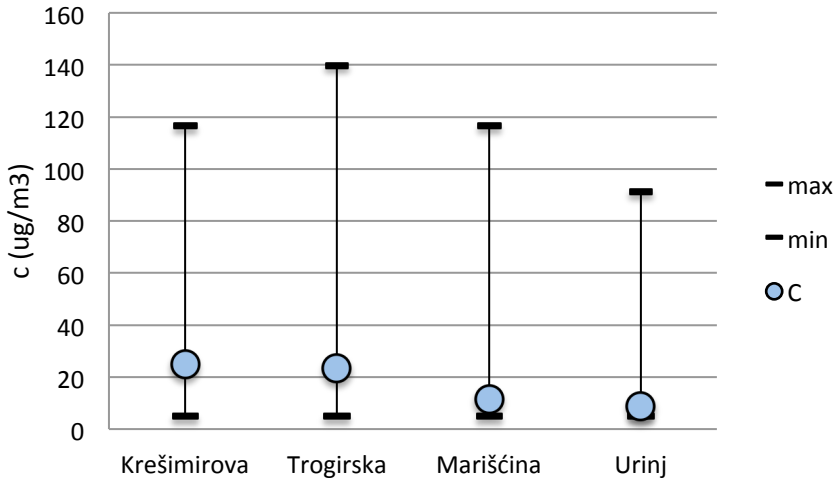

Figure 2: Distribution of NO_2 at four monitoring stations during the period March 2018-September 2019.

In spite of low NO_2 concentration measured, higher levels in urban area shows impact of road traffic. In the period studied no exceedance of hourly limit value (200 µg/m^3) was observed. 98th percentile,

[2] Uredba o razinama onečišćujućih tvari u zraku/Directive on air pollution levels (NN 117/12 i 84/17).

i.e. the value bellow which 98% of measured results are found (excluding 2% of maxima) were 74 and 86 µg/m^3 for two urban sites, respectively Trogirska st. and Krešimirova st. , and considerably lower for remote Marišćina (44 µg/m^3) and industrial sites Urinj (38 µg/m^3)-

Descriptive statistics, e.g. average value, minimum and maximum for PM_{10} at four monitoring sites is given in Fig. 3.

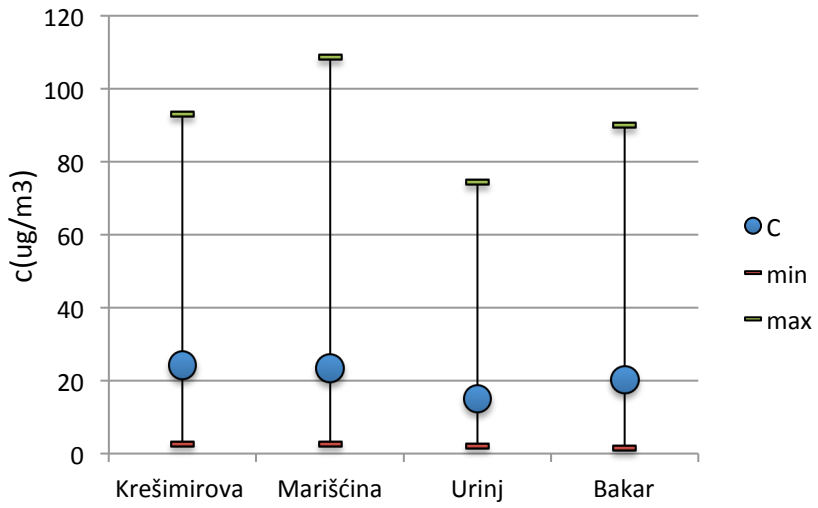

Figure 3: Distribution of PM_{10} at four monitoring stations during the period March 2018-September 2019.

The average daily PM_{10} concentration in three of fourth sites are in the close range between 20-24 µg/m^3, but for different reasons: road traffic in urban site (Krešimirova St.), construction works carried out in suburban site (Marišćina) and dust emission from bulk reload in industrial/harbor site Bakar, taken here for comparative reasons. The industrial site Urinj has a lower mean (15 µg/m^3) as petroleum refinery is not a significant source of airborne particulates. 98th percentile is approx. 50 µg/m^3 at urban Krešimirova St. and industrial Bakar site, at the suburban site Marišćina this value is higher (72 µg/m^3) due to already mentioned construction works. The lowest C_{98} value is obtained in industrial site Urinj (33 µg/m^3).

Time series of daily average PM_{10} concentrations at four monitoring sites: Marišćina, Urinj, Bakar and Krešimirova St. are given in Fig.4.

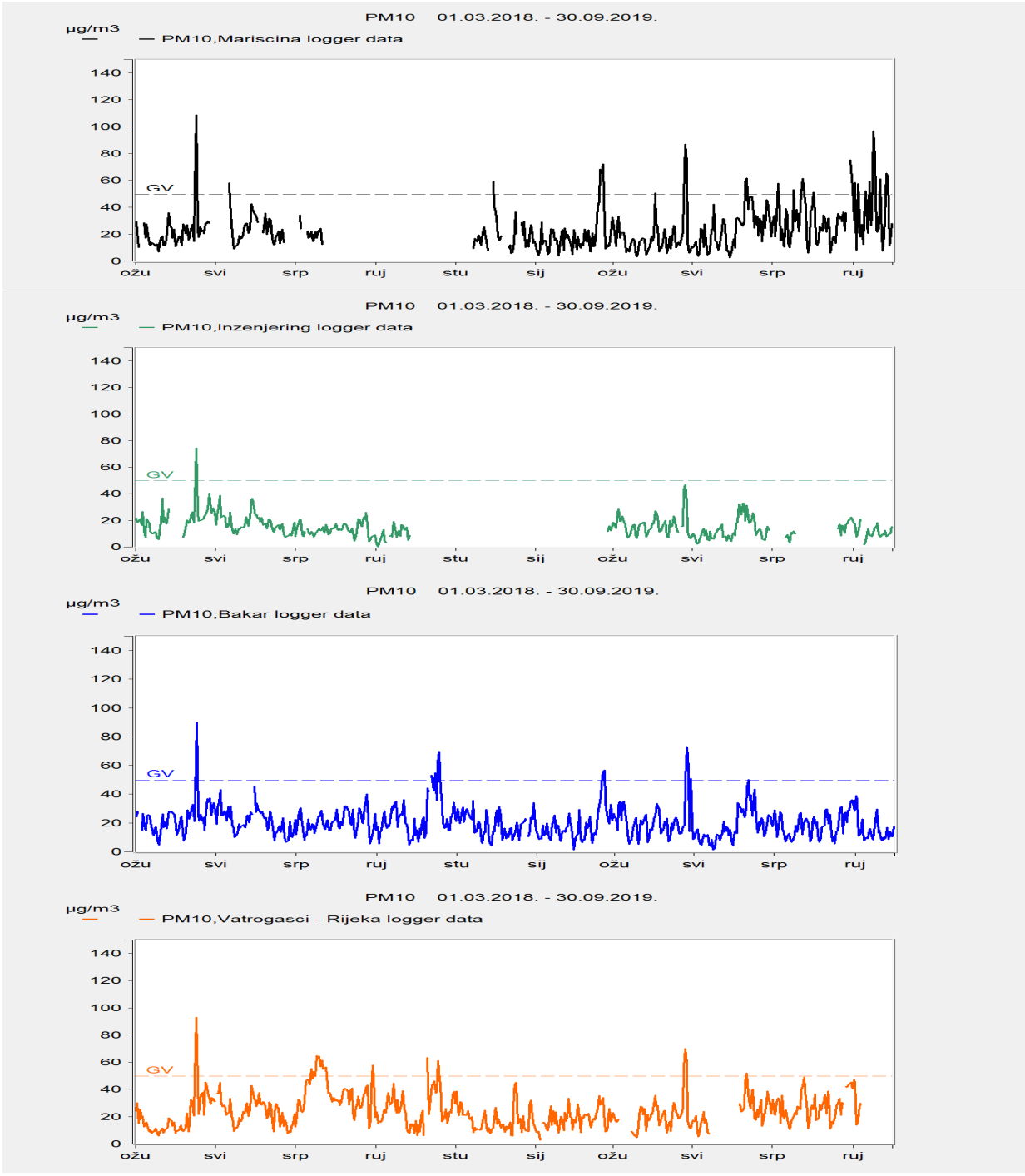

Figure 4. Daily average PM_{10} concentration during the period March 2018 - September 2019.

The limit value for PM_{10} is 50 µg/m^3 as daily average[2] and can be exceeded no more than 35 times per year. The number of these exceedances are reported in Table 2. Number of exceedances are <35, as

Table 2. Number of exceedances of PM_{10} of the daily law limit. In red the number of exceedances above the law limit

Station	Mar-Dec 2018	Jan-Sept 2019
Krešimirova St.	14	4
Marišćina	4	25
Urinj	1	0
Bakar	5	6

regulated by the Croatian directive (equal to the corresponding EU document). Though there are just few exceedances in Urinj and Bakar, the situation is changed in Krešimirova, reducing the number of exceedances in period Jan-Sept, while at Marišćina this number is increased. Both sites have the same sources of elevated particulate pollution: the construction works.

CHRONOLOGICAL TREND

The monthly trend of monitored pollutants for the period studied is shown in Fig.5. Both NO_2 and PM_{10} behave differently: a higher concentration of NO_2 has been measured in urban areas (Site 1 and 2), in

a. b.

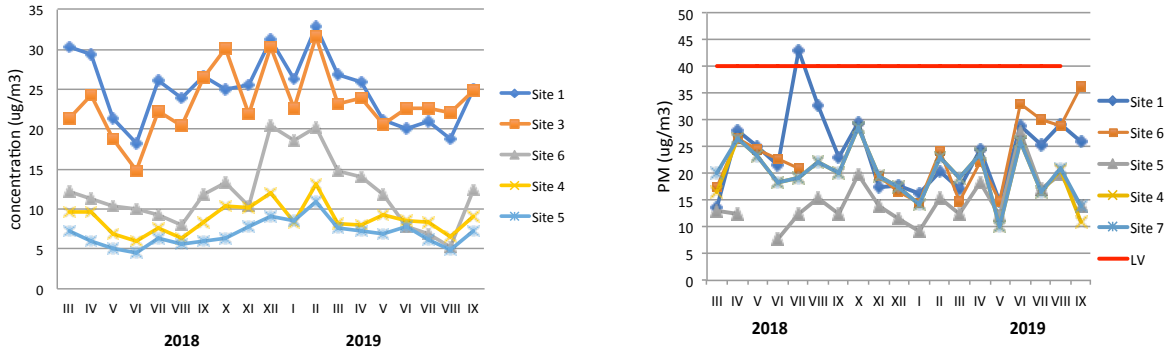

Figure 5. NO_2 (a) and PM_{10} (b) monthly average concentration in the period March 2018 - September 2019.

winter months, while monthly means show higher values in summer months in all sites. Unlike NO_2,

[2] Uredba o razinama onečišćujućih tvari u zraku/Directive on air pollution levels (NN 117/12 i 84/17).

there is no difference in PM_{10} monthly profiles between urban and suburban sites.

Seasonal diurnal profiles are also different (Fig.6).

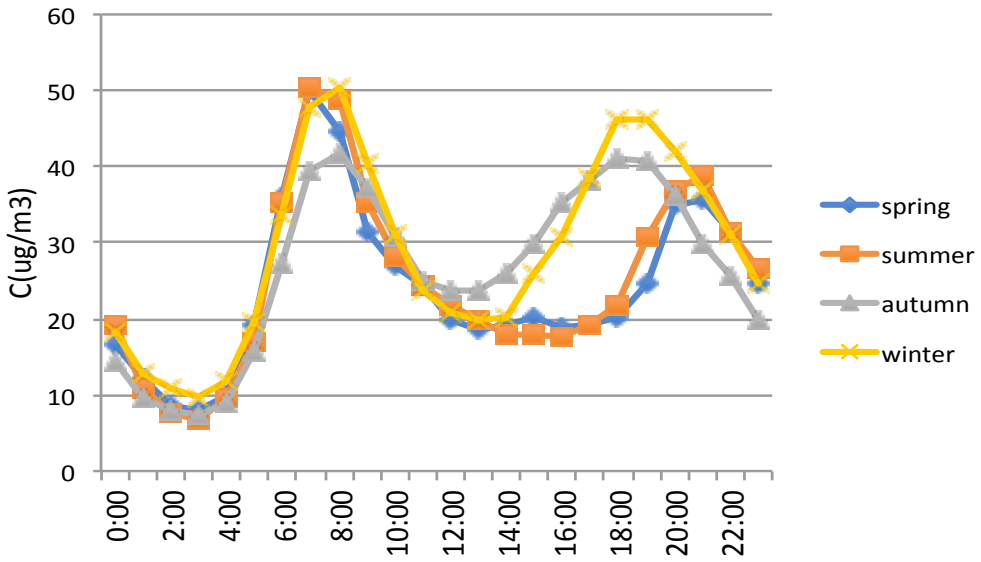

Figure 6. Diurnal concentration of NO_2 in spring and summer at urban site Krešimirova St

Diurnal NO_2 concentration for urban site Krešimirova ul. shows typical bimodal curve with morning and evening maxima during rush hours. The morning profile maxima for three seasons overlp at 7AM, except in autumn when is somewkat lower (maybe due to rainy weather in autumnI). Contrary to morning maximum, the evening one at 9 PM overlaps in spring and summer, and is probably conected to increased traffic in evening hours, but also photochemical cycle during daylight. This maximum is shifted to 6 PM in autumn and winter, and might be connected to domestic heating in early evening.

The situation is different with PM_{10}, whose diurnal profle per season is given in Figure 7. Unlike other cities where PM_{10} is maximal in the heating season in winter, the concentrations of PM_{10} are the highest in summer and lowest in winter. The reason for such a profile could be the extended construction works in the vicinity, but also frequent Saharan dust episodes observed in 2018. Autumn and winter diurnal profiles are similar to that of NO_2, indicating ther same sources, mainly zraffic and domestic heating.

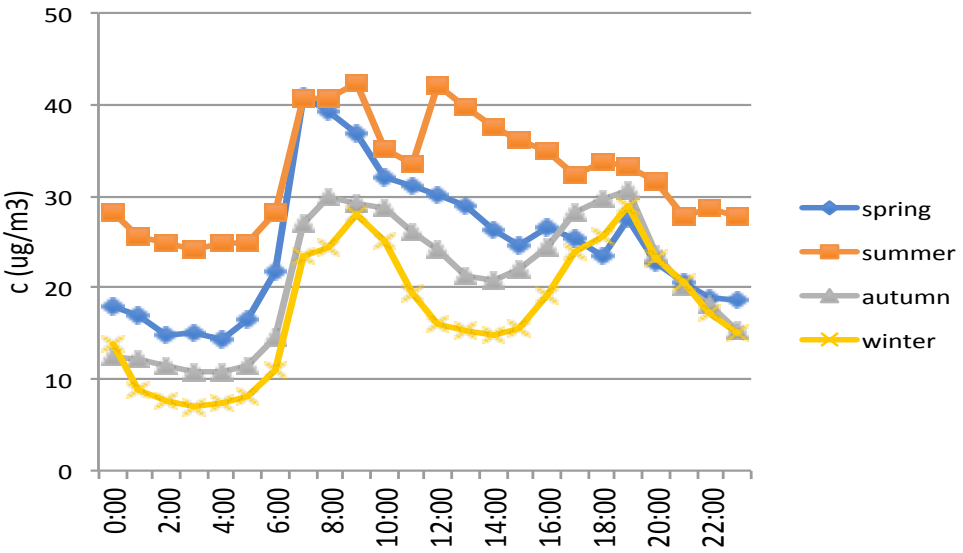

Figure 7. Diurnal concentration of PM_{10} at urban site Krešimirova St

Diurnal concentrations of NO_2 and PM_{10} over the whole period studied at four different monitoring stations are given in Fig. 8 and Fig. 9.

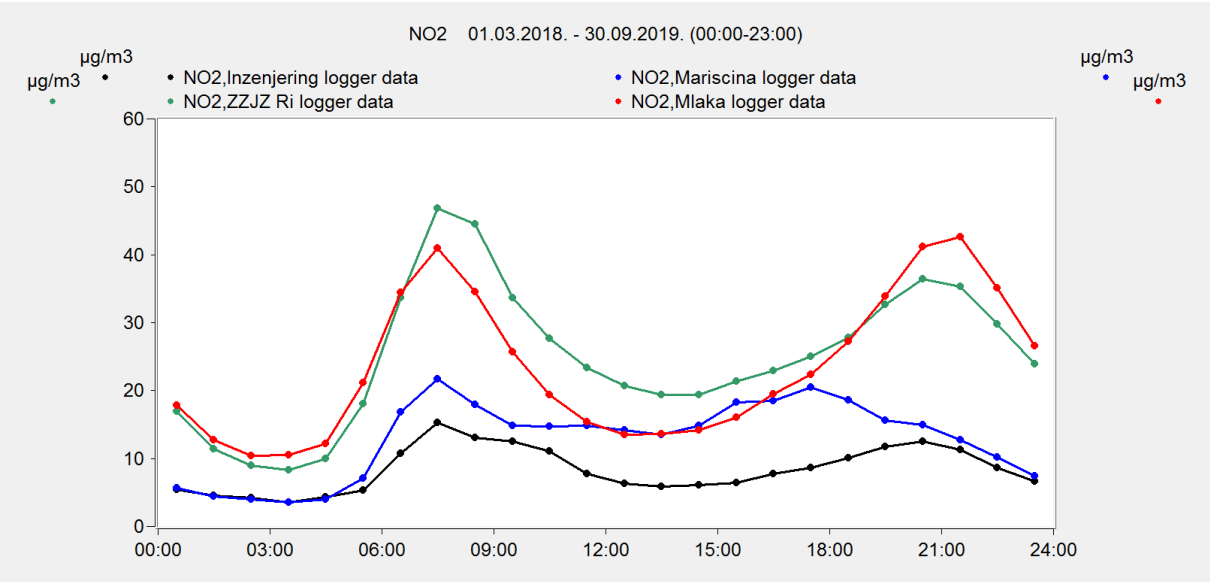

Figure 8. Diurnal concentration of PNO_2 at two urban sites (Krešimirova St - ZZJZ and Trogirska St.-Mlaka), a suburban (Marišćina) and an industrial site (Urinj-Inžinjering)

As expected, the two urban sites show higher NO_2 concentrations, but with slightly different diurnal profiles:at urban background site Krešimirova St (ZZJZ) the morning maximum (7 AM, up to 45 µg/m^3) is slightly higher than the evening one (9 PM, up to 35 µg/m^3), while at residential site Trogirska St. (Mlaka) the situation is just opposite, presumably due to meteorological conditions due to complex orography.

The profile cocentrations are 2-3 times lower (10-20 µg/m^3) at suburban and industrial sites, with stil visible morning and evening maxima. Though, the diurnal profile at suburban site located at 450 m asl appear at 6PM, presumably due to being under strog impact of land-sea circulation that starts around 6 PM.

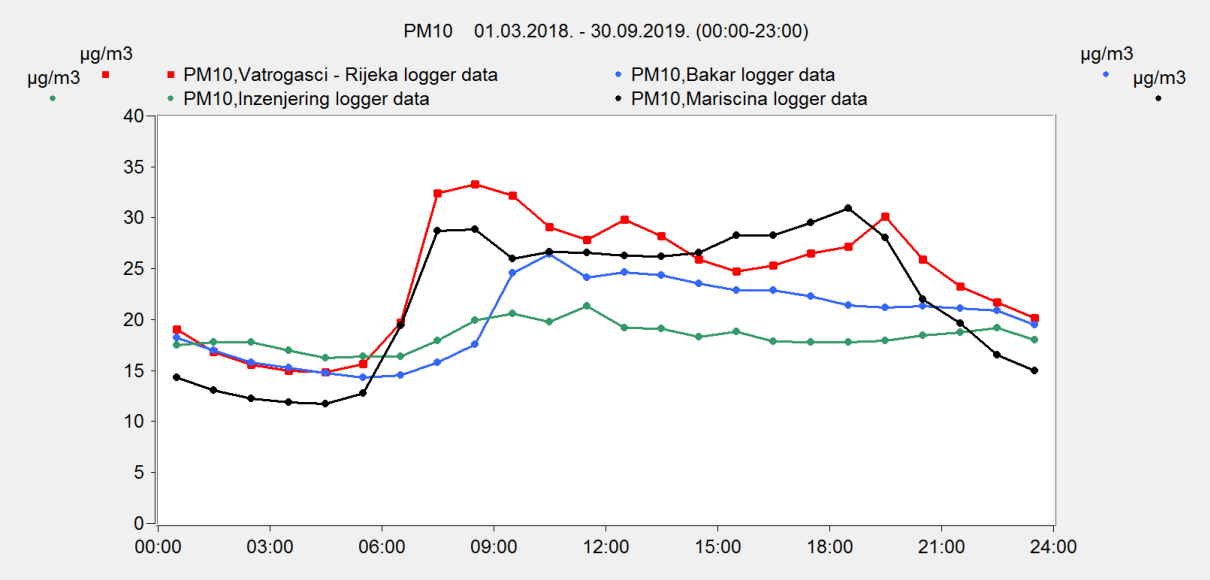

Figure 9. Diurnal concentration of PM_{10} at an urban site (Krešimirova St), a suburban (Marišćina) and two industrial site (Urinj-Inžinjering, Bakar)

The PM_{10} diurnal profile for the whole period studied (March 2018-September 2019) shows a rise in PM_{10} (up to 30 µg/m^3) in morning hours (6-7AM) at urban and suburban site coinciding with start of the activities, and maintaining this level until 6- 7 PM at suburban Marišćina (due to land-sea breeze) and 8 PM at urban site Krešimirova when most of commercial activity stops. The profile is different for industrial site Bakar, probably connected to the reloading process starting about 9 AM, and slightly diminishing the whole day. Industrial site Urinj shows practically no trend, since the petroleum refinery is not signid+ficant emitter of particulates.

The weekly profile shows an expected decrease in concentrations during Saturday and Sunday, for both NO_2 and PM_{10} (Fig. 10-Fig.11.).

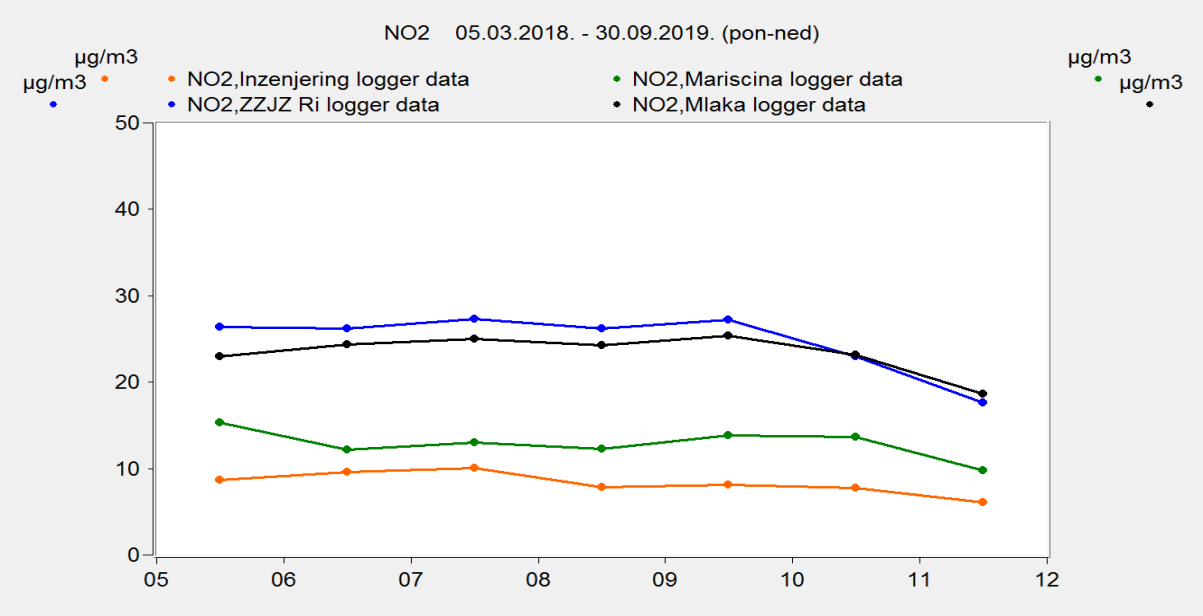

Figure 10. Average daily concentrations of NO2 during t a week at two urban sites (Krešimirova St and Trogirska St-Mlaka), a suburban (Marišćina) and an industrial site (Urinj-Inžinjering

Thus the weekly profile of NO_2 distinguish the behaviour of two urban sites (Krešimirova – ZZJZ and Trogirska- Mlaka) with an average daily concentrations of approx. 25 µg/m^3 from Monday to Friday, declining to approx. 20 µg/m^3 on Saturday and approx. 20 µg/m^3 on Sunday. Suburban site Marišćina shows a different profile with highest mean daily concentration of 15 µg/m^3 obtained on Monday, with a slight decrease on Tuesday and keeping that level until Saturday, and a final decrease to approx. 10 µg/m^3 on Sunday. Such a profile is correlated to the nearby activity of the solid waste treatment plant, that does not work on Sunday, and therefore more traffic with solid waste is expected on Monday.

There is almost no trend in NO2 concentrations at the industrial site Urinj-Inžinjering (daily average < 10 µg/m^3) , since the facilities are constantly working during a week.

Similar situation is found with weekly profiles of PM_{10}. The average daily concentrations were approx.. 25 µg/m^3 at urban (Krešimirova—ZZJZ) and suburban siites (Marišćina) from Monday to Friday subsequent to a slight desrease since Saturday (Marišćina) and Sunday (Krešimirova st.).

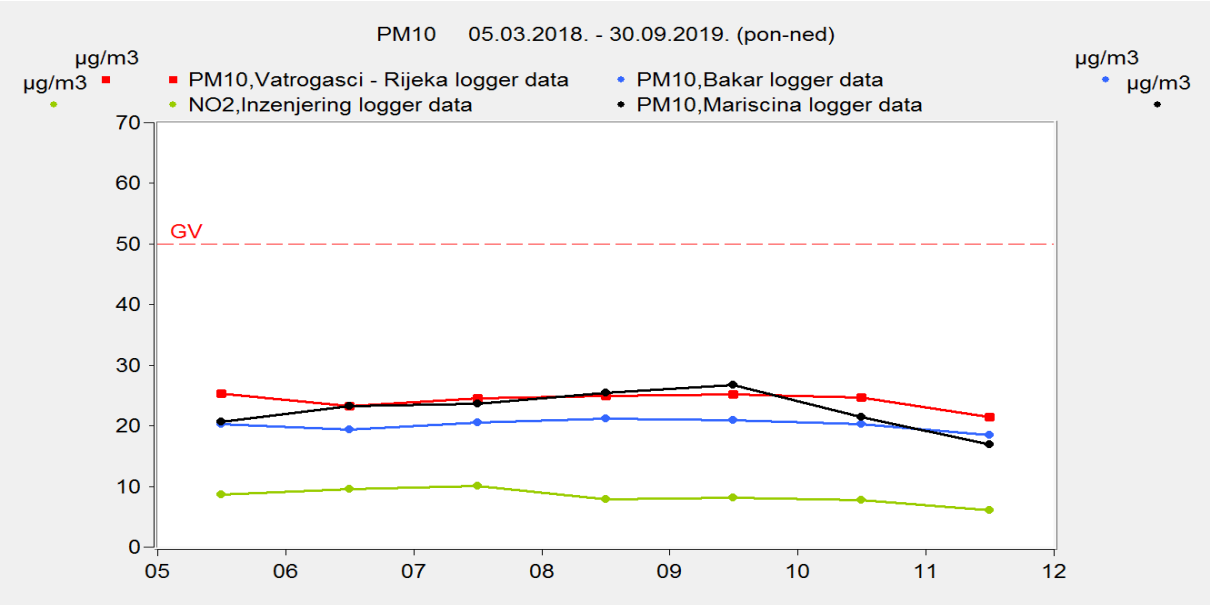

Figure 11. Average daily concentrations during a week at an urban site (Krešimirova St), a suburban (Marišćina) and two industrial site (Urinj-Inžinjering, Bakar)

No trend is found in daily concentrations of PM_{10} (20 µg/m^3) at industrial site Bakar, while very slight declining trend (from 8 to 5 µg/m^3) is noticed at industrial site Urinj (Inžinjering).

RESULTS FROM THE NEW MONITORING STATION

Implementation of ECOMOBILITY project included establishing a new monitoring station in the passenger port area, at the Harbourmasters' Office. For this purpose the City of Rijeka purchased a new compact monitoring system Air Pointer (Recordum, Austria) that contained NO2, O3 and PM analysers with complete meteorological sensors. Due to long public procurement procedure, the monitoring system was installed only at the end of May, but due to some technical troubles the transfer to Venice was realized only in mid September. This is the first evaluation of air quality data collected in the passenger harbour area. The monitoring system is located at the terrace of the Harbourmasters' Office building (Fig 12), between the container and pasenger area.

Figure 12. Compact monitoring system (Air Pointer, Recordum, Austria) used to monitor NO_2, PM_{10} and O_3 in the harbour area

The results analysed compridse the period of September 14th to december 3rd, 2019. Hourly data of given parameters are analysed and presented in Table 3.

Table 3.: First results of monitoring air quality within Rijeka passenger port

Time unit (N)		Parameters c (ug/m3)			
month	h	NO2	O3	PM10	T (oC)
September	400	10,9	30,7	10,2	20,1
October	744	11,1	25,6	16,5	17,3
November	720	10,3	23,0	9,3	13,8
December	75	8,5	25,9	6,4	2,7
	Total	10,6	25,7	12,2	16,3
	max	71,8	63,1	65,6	28,2
	exceedances	no	no	no	

Average concentrations of all three paramaters monitored over te whole period are rather low. The mean concentration of NO_2 is 10,5 µg/m^3 (monthly range 10,3-11,1 µg/m^3), while the maximum

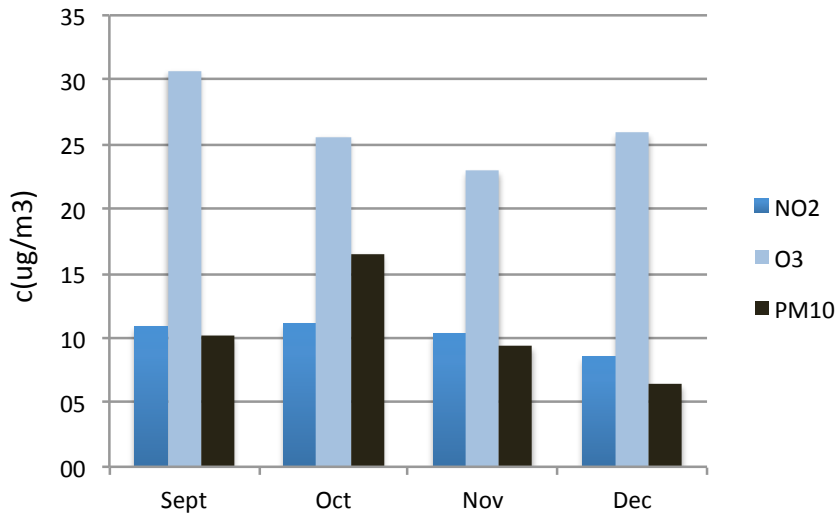

Figure 13. Monthly average concentration NO_2, PM_{10} and O_3 at new monitoring Site 2 in the port area

hourly value of 71,8 µg/m^3 is bellow the hourly limit value of 200 µg/m^3. Mean PM_{10} concentration of the whole period is 12,2 µg/m^3 (9,3-16,5 µg/m^3), at the same level as NO_2. The highest hourly concentration is 65,6 µg/m^3, but measured on 28/10/2019, when the daily concentration was 24,4 µg/m^3, bellow the daily limit value (50 µg/m^3). Both PM_{10} and NO_2 concentrations are about the half of the values registered in heavy traffic urban streets. Therefore we need more monitoring within the

wide and open harbor areas. On the other site, concentration of O3 is similar to that measured earlier in the city center. Hourly values of NO_2, PM_{10} and O_3 are given in Fig.14. The wind rose made upon

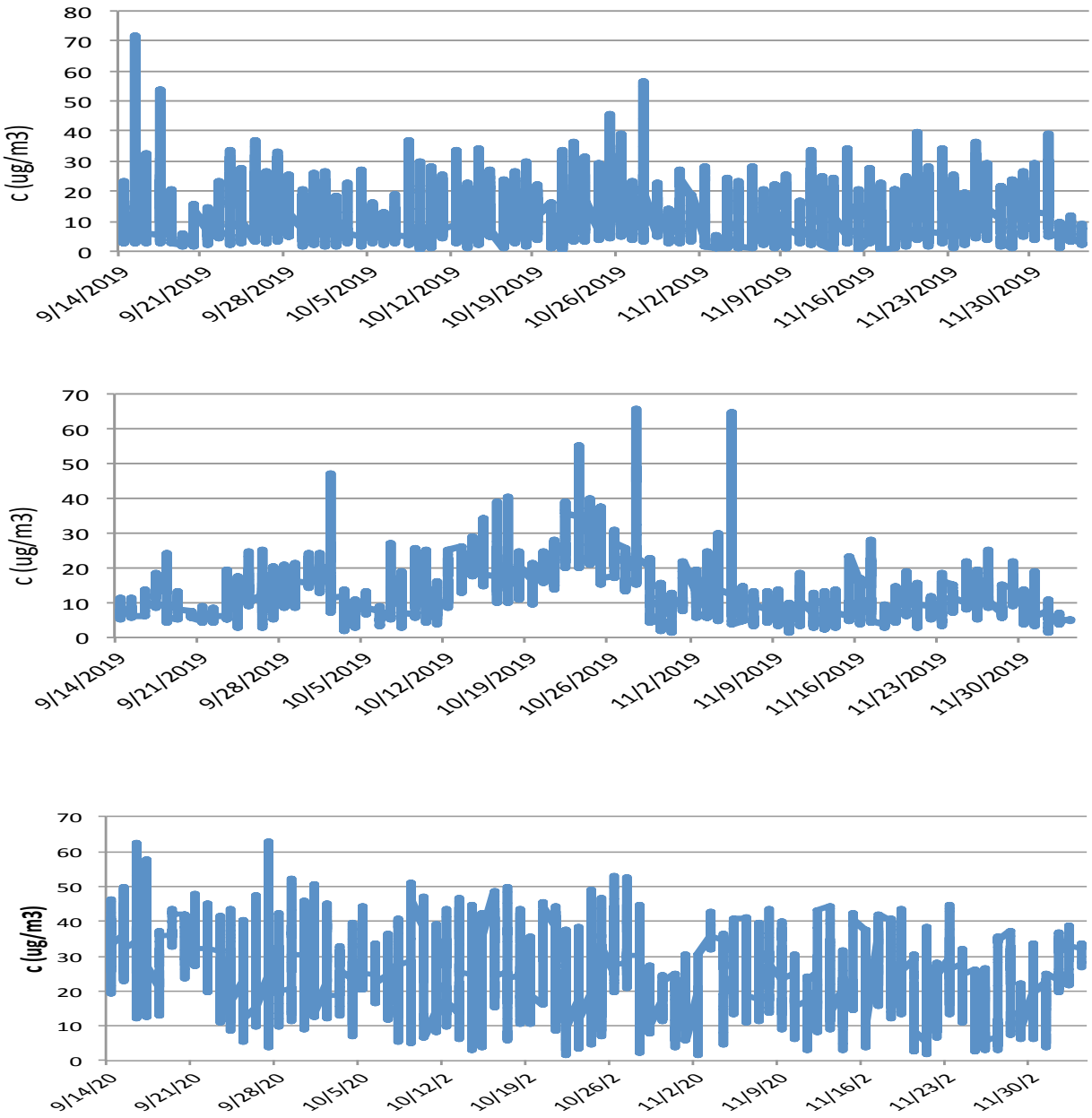

Figure 14. Time-series of hourly concentration of NO_2, PM_{10} and O_3

first results on the new monitoring site indicated the domination of east winds (Fig.15), NE with higher frequency but low velocity blowing in direction land-sea, and stronger E-SE winds from the harbor area and sea thus justifying the lower concentration of pollutants, already diluted above sea surface.

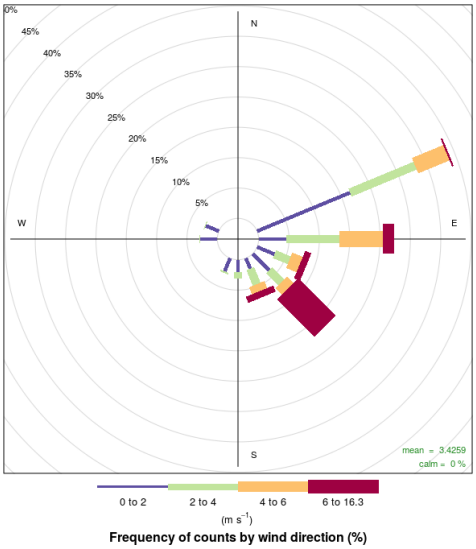

Figure 15:Wind rose for the new monitoring site in the harbor area

The cpf function obtained from the respective 75%- percentile indicated major sources of monitored pollutants (Fig.16). While the source of PM_{10} is principally container harbor Brajdica (ESE) , other directions indicates the nearby Porto Baros. The situation is different with NO_2 , with significant

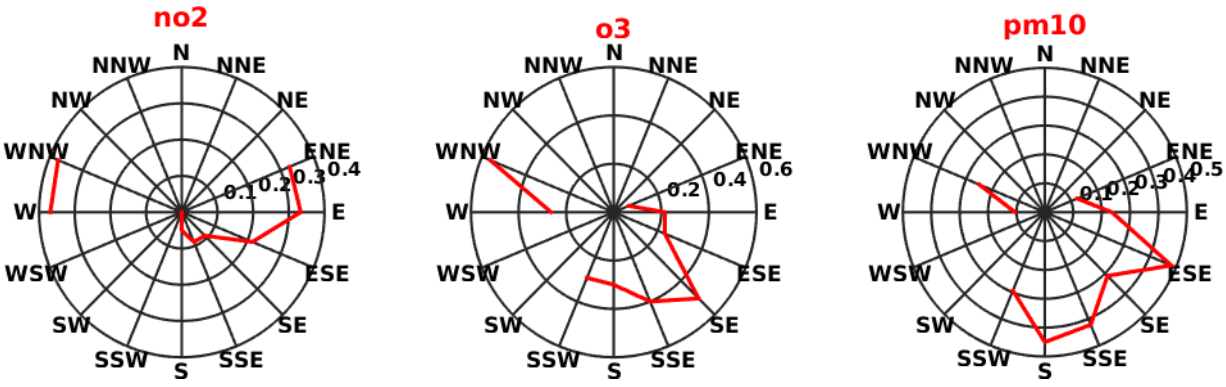

Figure 16: Cpf functions of monitoring pollutants at the new monitoring site in the harbor area

contribution from ENE-E sector. This could be attributed to road traffic, but also to air mass circulation in the Rijeka bay. The situation is different with ozone, a secondary pollutant, coming mostly from the sea surface level, but also from the WNW direction that was detected in the city center, and attributed either to local airmass circulation in the Kvarner bay area, or even transboundary transport.

These are preliminary results for the harbor area, and it would be highly advisable to include this station in the local Air Quality Monitoring Network