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PARTICULATE MATTER AND HEAVY METAL AIR POLLUTION IN THE MIDDLE EAST REGION

TAMÁS MERÉTEI–PÁL ZOLTÁN BITE–
CSONGOR BÁTHORY[1]–ZSUZSANNA BOLLA[2]

The purpose of the research was to evaluate the background particulate matter pollution originating from the barren, desolate desert region and from the sea side. Another objective of this paper is to show the metal content in PM_{10} in a major city in the GCC region grouped by sources and compare them with the results measured in Hungary.

Keywords: PM_{10}, $PM_{2.5}$, heavy metal air pollution

INTRODUCTION

One of the most developing areas around the world is in the Middle East region within those countries of the Gulf Cooperation Council (GCC), where the focus on environmental protection is increasing at a great extent. Beside the noise, groundwater and nature protection, more and more emphasis is placed on air quality protection. The residents are annoyed by the busy roadways and many of the industrial plants, but the main source of annoyance is still the transportation. The number of cars per capita, the built dwelling houses and buildings under construction even at 30 meters from the edge of the highways as well as regulatory failures do not facilitate the job of the local environmental authorities. Extreme weather and terrain conditions make it a challenge for even the best teams and monitoring instruments to carry out evaluated air quality measurements.

1. EMISSION SOURCES

The research had begun to map the main anthropogenic emission sources. One of the major emission sources in major cities of the GCC region is the transportation. In our estimation from the emitted PM_{10} it is around 63% (including road traffic, seaport and airport emission). The second major source is the emission of the industry with 15%, after that the non-road emissions and power plants around 10%.

1.1. Road traffic

Road traffic is responsible almost for the half (43%) of the transportation's PM_{10} emission. *Table 1* shows the development of vehicle number per 1000 capita of Hungary and that of the GCC. Data are credible from western counties, and is limited from eastern regions due to the publicity of statistics. Qatar and Kuwait are much smaller and have less desert areas,

[1] csongor666@gmail.com
[2] info@vibrocomp.com

so the densely populated area is the reason of the higher numbers. It is also worth mentioning, that the City of Dubai's vehicle density was 540 per 1,000 people in 2015 [1].

Table 1

Vehicle per 1000 capita, 2005–2014 [2] [3]

Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Hungary	329	337	345	351	347	345	342	347	355	366
Kuwait	426	426	430	429	433	444	458	469	475	482
Qatar	443	381	390	449	421	413	420	432	432	442
Saudi Arabia	145	147	153	158	165	173	183	193	197	202
United Arab Emirates	193	170	180	204	185	173	179	188	202	216

Figure 1 shows the percentage change in vehicle per 1000 capita values compared to the previous years. The most significant changes were in Qatar and the United Arab Emirates and by evaluating these and Hungary's values the effect of the 2008 world economic crisis can also be observed. From 2011 – except Hungary-, the values show an increasing tendency, which even lasts to the present day. This hectic, but strong growth tendency makes the road traffic the most important and key player in case of emission sources.

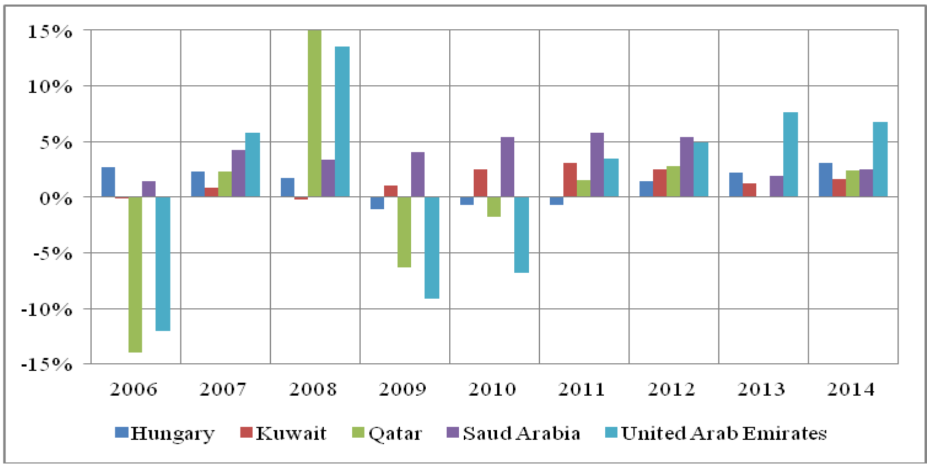

Figure 1

Percentage changes in vehicle per 1000 capita values, 2005–2014

Data are not available corresponding to the composition of the vehicle fleets and due to the lack of emission categories it is even hard to estimate. Based on observations, it can be said that among individual types of passenger cars, the most powerful models are distributed to the GCC area. Heavy trucks are usually in worse condition, the use of the latest models and the use of catalyzer is not typical in this area. In our estimation vehicle fleet correlate well with the German passenger car fleet of 2010 and the German heavy duty vehicle fleet of 2008.

1.2. Seaport

Three ports from the GCC region are among the top 50 world container ports in 2015. These were the Jebel Ali Port (United Arab Emirates) being the 9th with 15.6 million containers, the Jeddah Port (Saud Arabia) being the 36th with 4.19 million containers and the Sharjah Port (United Arab Emirates) being the 44th with 3.4 million containers [4]. These numbers show that the ports' emissions can't be neglected in the Arabian Gulf. As part of the International Convention for the Prevention of Pollution from Ships (MARPOL), the International Maritime Organization's (IMO) members agreed at a global 0.5 Vol% limit on sulfur content for 2020. This is less restrictive than European and North American regulations, but 0.5% still represents a significant cut from the 3.5% global limit currently applied and it would make the Middle-East's current regulations redundant [5]. Besides the pollution from ships, the emission of service facilities and auxiliary engines and machines are also contributing to the overall emissions.

1.3. Airport

Airports have a significant traffic in 24 hours and usually are close to the city center. Airplanes are flying at a low altitude over the city, and the auxiliary vehicles, engines and traffic around the airports also makes airports a considerable source of air pollution. As the cities are growing they are likely to be built around the airports as well, therefore residential building will be too close to the airports, leading to a noise and air quality problem as well. Restructuring of airports and/or expansion is expected due to the above reasons. For example the secondary airport of the Emirate of Dubai (DWC), which is at the edge of the city, is now being expanded from the current capacity of 5 million passengers a year to 26 million by 2018 [6].

1.4. Industry

The main activity is corresponding to the petroleum industry – pollution sources mainly corresponding to oil refining and the use of petrochemicals products. Metal industry is also present due to the ports' import capacity, but because of lack of local raw materials it is not significant. The beverage and food factories are significant and following the needs of the market, which is of a high extent.

Lot of small garages and workshops are not controlled in terms of air quality. Public waste oil delivery locations were not found. Concrete industry is largely present with vigorous utilization, because of the individuals' building needs and also large public investments. Filtration of stack gases is rudimentary, small and large factories have filters, however separators are rarely incorporated into those.

1.5. Power Plant

Emission inventory is to be improved because presently there is no well-developed mandatory emission collection system. Two or three times larger Combined Cycle Gas Turbine (CCGT) power plants are in a major city as much as Paks in Hungary (2000 MW), for example, the Emirate of Abu Dhabi has a 9940 MW, the Emirate of Dubai has a 3066 MW, whole Kuwait has a 5000 MW and whole Qatar has over 9000 MW power plants [7]. The power plants are usually built together with desalination plants to secure the water supply in the subtropical climate.

2. SAMPLING METHOD

2.1. Sampling points by types of sources

The sampling points were appointed by the sources and the residential areas like Background, Road, Port, Airport, Industry, Residential and Rest Area. Sampling results are averaged by sources' type.

2.2. Sampling method

PM_{10} and $PM_{2.5}$ were sampled with a high volume sampler using a quartz filter and were analyzed by gas chromatography to specify the metal content in PM_{10}. The evaluation focused on lead (Pb), nickel (Ni), cadmium (Cd) and arsenic (As) metals. Samples to be analyzed for the sand and sea salt content were treated with PTFE filters to be measurable. Sampling has been carried out during winter and spring time in 2015–2016.

3. SAMPLING RESULTS

3.1. PM_{10} and $PM_{2.5}$

15% of PM_{10} values exceeded the 50 $\mu g/m^3$ values. 17% of the sampled values were over 100 $\mu g/m^3$, mainly at Industry and Road sampling point types, and even at Background. The average PM_{10} value was 75 $\mu g/m^3$.

$PM_{2.5}$ was sampled at the following sampling point types: Background, Road, Airport, Industry and Residential. The average $PM_{2.5}$ value was 28 $\mu g/m^3$. The results showed that the average $PM_{2.5}$ content in PM_{10} was around 40%. The lowest content was found at Background, where it was 23%. $PM_{2.5}$ values were at the same level, except one Industry sampling point was higher. At this particular point, PM_{10} was the lowest as well, probably it occurred because of the meteorological conditions during sampling (rain was recorded).

Sea salt (NaCl) and quartz (SiO_2) were analyzed from the PM_{10} samples to find out the sand and sea salt content. The analyses' results showed that 56% of the weight of sampled PM_{10} is SiO_2 and 3% is NaCl *(Figure 2)*. The salinity of particulate matter is approaching the average salinity of sea (3.5%). Soil and sand composition is unknown at the sampled area. Quartz could also come from different sources (construction activities, wear of road pavement and re-suspended road dust). It is important to notice that a significant proportion of PM_{10} is coming from natural sources, as that percentage distribution of sea salt and quartz in PM_{10} was the same in background samples.

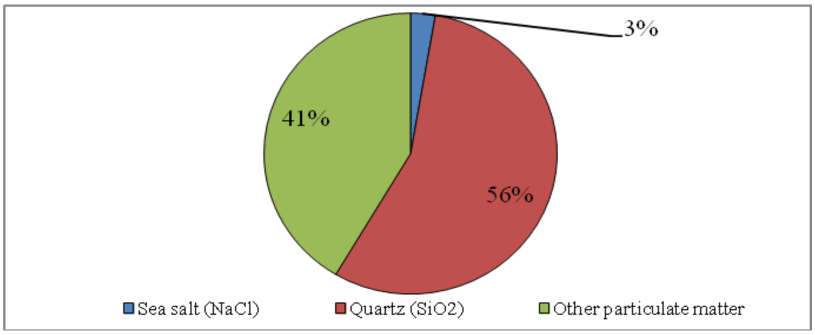

Figure 2
Average percentage distribution of sampled PM_{10}

The sampled values were averaged by sample areas, which represent the seven (7) source types and the average values. To compare the Hungarian data [8] we have chosen six (6) monitoring station from the stations of the Országos Légszennyezettségi Mérőhálózat **(**OLM) (National Air Pollution Monitoring Network), where PM_{10} and metal contents were monitored during 2015. Hungarian samples were taken in 4x2 weeks periods during 24 hours according to standards [8]. *Table 2* shows the chosen monitoring stations, their type and the conformity to source types. The conformity is acceptable, Gilice tér is a Rural background, but approximates the Airport type.

Table 2

Conformity of OLM monitoring stations

Monitoring Station	**Monitoring Type**	**Source Type**
K-Puszta	Background	Background
Budapest, Széna tér	Urban traffic	Road
–	–	Port
Budapest, Gilice tér	Rural background	Airport
Dunaújváros, Apáczai Csere J. u. 3.	Urban industry	Industry
Győr, Szigethy Attila út	Urban background	Residential
Sarród, Nemzeti Park	Rest area	Rest Area
Average of Above	Average	Average

The comparison of PM_{10} values is shown on *Figure 3*. All Hungarian values are less than the GCC values. Background is higher in average at GCC as well and the rest area in GCC is significantly higher compared to the pattern in Hungary. Port area is next to the sea side, so the background pollution from desert side does not appear there.

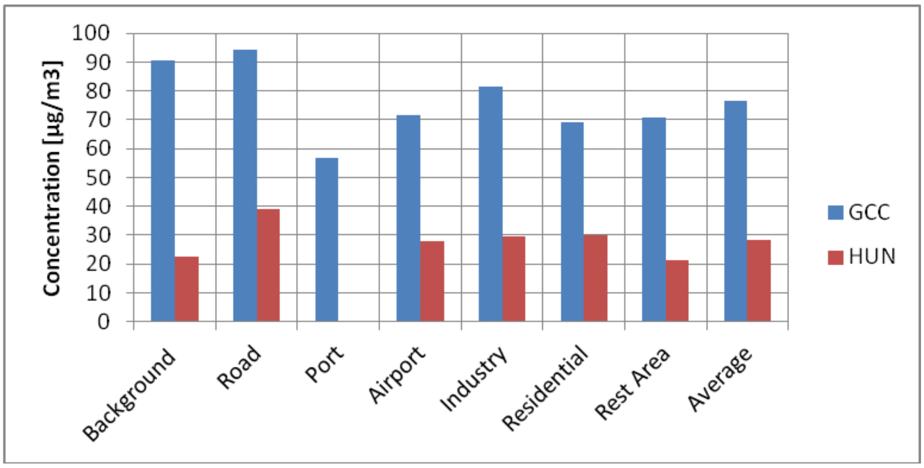

Figure 3

Average PM_{10} values [8]

$PM_{2.5}$ results are limited in both regions; therefore we did not compare those values.

3.2. Lead (Pb) and Nickel (Ni)

The metal content of PM_{10} was calculated to part per million percentage (ppm) by the weight of PM_{10} per m^3 and by the weight of the metal per m^3. The values of different regions are comparable with this method; the percentage distribution of metals shows the typical composition. The Pb and Ni content of samples can be seen on *Figure 4*.

Pb content in percentage was three times higher (Airport) or even five times higher (Road) in Hungary, except at the Rest Area, where it was almost the same percent. As the Pb content is almost the fifth at Background in GCC, it can be concluded that Pb pollution is not significantly coming from desert and sea side.

It can also be seen that the Ni content, in Hungary has much lower percentage. At the Port side in GCC it is the highest, but also the Industry and Rest Area are outstanding in Ni content. The high Ni content at Background added to the other sample areas, except covered areas, like paved road (Road, Airport) and lawn or built territories (Residential). It can also be seen that Pb and Ni contents are the lowest in GCC at Road.

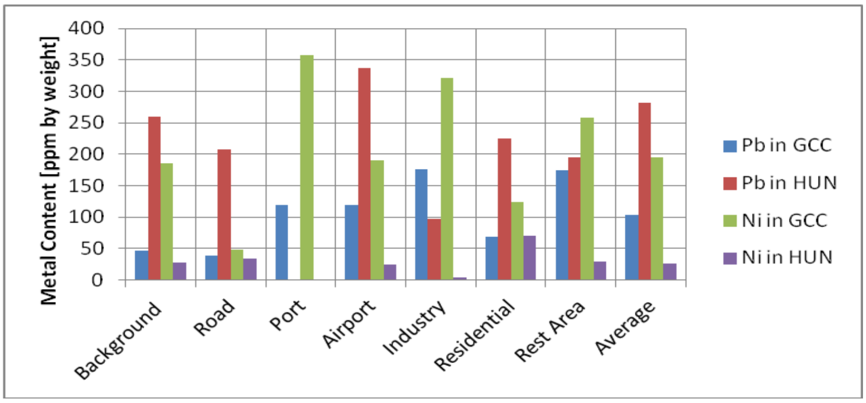

Figure 4
Lead and Nickel content [8]

3.3. Cadmium (Cd) and Arsenic (As)

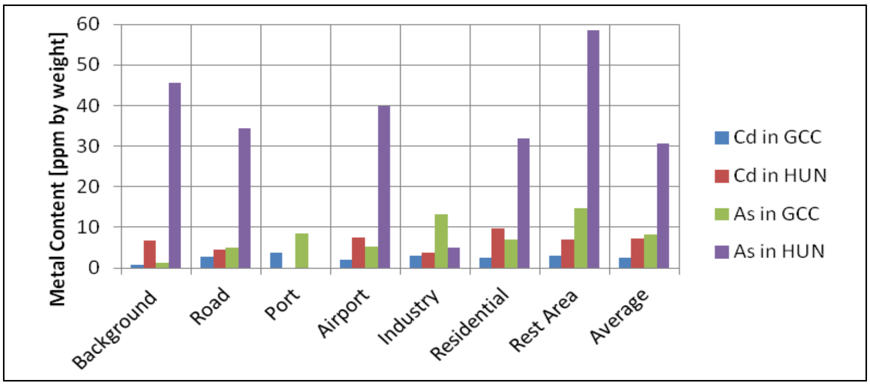

Figure 5
Cadmium and Arsenic content [8]

Figure 5 shows the Cadmium and Arsenic metal content of average PM_{10} samples. Cd content in percentage is much lower in GCC, especially at Background. The ppm values in GCC and Hungary are near to each other at Industry and Road. The lowest Cd percent is at Industry in Hungary. Residential Area has four times more percentage Cd content in Hungary than in GCC.

High As percentage content in Hungary is immediately noticeable. In GCC this value is the highest at Rest Area. But at Industry types, GCC values are higher than in Hungary – actually these are the lowest in Hungary. Except Industry, as content in percentage is much lower in the GCC, especially at Background.

CONCLUSION

The examined PM_{10} values are higher in the GCC than in Hungary. In GCC the natural background sources are contributing more to the PM_{10} values. In Hungary the high PM_{10} values are usual measured during winter time due to the domestic heating; the background pollution isn't significant compared to GCC.

Surrounding of roads have the highest PM_{10} values in both regions. Compared to this, examined metal percentages are the lowest. It means that a significant part of PM_{10} samples are mixed with other components. PM_{10} emission of road traffic is mostly composed of vehicles engine emission, wear of road pavement and re-suspended road dust. Based on the high SiO_2 content and low Pb percentage of PM_{10} samples in the GCC, proportionally next to the background pollution, the re-suspended road dust is a significant emission source.

Port area is next to the sea side, so the background pollution is not significant there. Pb and Ni percentages can be higher because of the lack of deserts' natural emission, and the industrial activities nearby.

Airport has less Cd, As and Pb percentage in the GCC as in Hungary and more Ni. PM_{10} values are less in the GCC than the Background value. The Hungarian sampling point was in a rural area therefore did not perfectly represent the effect of nearby airport.

Industry in the GCC has the second high PM_{10} value, examined metal percentages are outstanding. Besides, there are higher Pb and As percentages than in Hungary.

Residential has one of the lowest Pb, Ni and Cd percentage in the GCC and As percentage isn't even over the Average. In Hungary Pb and Ni are over, Cd and As are under the Average.

Rest Area has the same PM_{10} values as Residential in the GCC, the metal contents are, however, lower, due to the vegetation and less road traffic. The same situation is present in Hungary, but Ni and As percentages are higher than in the GCC.

Ni content in percentage is much lower in Hungary, especially at Industry. The higher values in the GCC require further investigation. As content in percentage is much lower in the GCC – except Industry – especially at Background. The higher values in Hungary require further investigation.

The parts per million calculation method of metal content in PM_{10} samples eliminates the high-value differences in $\mu g/m^3$ dimension and make the values comparable in the GCC and in Hungary.

If we consider that high proportion of PM_{10} in the GCC is coming from background, it is hard to imagine how to reduce, but environmental regulations and best available technologies are good options to decrease the anthropogenic air pollution to a sustainable air quality level. Although the Hungarian and the GCC regions must face different challenges, we should keep an eye on countries, which do not understand the word "impossible", waiting for any new breakthroughs in order to provide a more livable environment.

REFERENCES

[1] Gulf News: For every two Dubai residents, there is one car. http://gulfnews.com/news/uae/for-every-two-dubai-residents-there-is-one-car-1.1472177 (Downloaded: 2017. 06. 25.)

[2] Organisation Internationale des Constructeurs d'Automobiles (OICA) – World vehicle in use 2014

[3] United Nations: World Population Prospects: The 2015 Revision, July 2015

[4] Top 50 world container ports. http://www.worldshipping.org/about-the-industry/global-trade/top-50-world-container-ports (Downloaded: 2017. 06. 25.)

[5] Asia Weekly: Shipping's Dirty Secrets. https://projects.asiaweekly.com/shippings-dirty-secrets/ (Downloaded: 2017. 06. 25.)

[6] Dubai Airport. http://damasterplan.ae/da-masterplan/dwc-passenger-terminal-expansion/(Downloaded: 2017. 06. 25.)

[7] Global Energy Observatory. http://globalenergyobservatory.org (Downloaded: 2017. 06. 25.)

[8] Országos Meteorológiai Szolgálat: Az OLM 2015. évi szálló por PM10 és PM2.5 mintavételi programjának összesítő értékelése, ÉLFO LRK Adatközpont, 2016. november