

# Assessment of air pollution of settlement areas in Ulaanbaatar city, Mongolia

**Ch Sonomdagva, Ch Byambatseren, B Batdelger**

Department of Environmental Sciences and Chemical engineering, School of Engineering and Applied Sciences, National University of Mongolia, Ulaanbaatar, Mongolia  
Email: ch\_sonomdagva@num.edu.mn

**Abstract.** The purpose of this study is to analyses mass concentration varied by its measurement of air pollution in Ulaanbaatar city, Mongolia. Ulaanbaatar city will have been increasing air pollution due to rapidly expanding vehicular population, growing industrial sector in last 10 years ago. In addition, people use to heat the carbon from 10 month in every year. This becomes a base cause of air pollution in Ulaanbaatar.

We studied a change of mass concentration an air pollution elements in Ulaanbaatar, Mongolia. To research work, we used information that based on data of my measurements of air pollution and Metropolitan air quality agency until 2006 to 2016.

This research important result is air pollution levels are limited to the areas around Ulaanbaatar areas are the most polluted in the center of city are the least polluted areas whereas Tolgoit, Sapporo, 1<sup>st</sup> Khoroolol, Amgalan, Shar Khad are moderately polluted and the areas around Baruun 4 zam, Factory, Zaisan, Nisekh are normally polluted. The results of pollution are illustrated four zones. By dividing the polluted areas into such zones, we are trying to make it easier to take preventive measures against the pollution itself and protective measures for safeguarding the health of mass population.

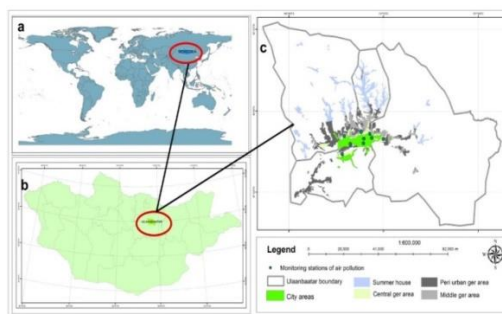
## 1. Introduction

This study area is with basic 6, cortege 3 districts, and only one capital city of Mongolia (Figure 1). The site surrounds the Bayazurkh, Chingeltei, Songinokhairkhan and Khan-Uul mountains and located an along of Tuul and Selbe river's valley in Mongolia center. Ulaanbaatar, the capital city of Mongolia, with a population of 1.1 million is located at an altitude of about 1350 m and in a valley. This study is the first to document the characteristics of the urban heat island (UHI) in Ulaanbaatar. The average UHI intensity is 1.6 °C. The UHI intensity exhibits a large seasonal dependence, being strongest in winter (3.3 °C) and weakest in summer (0.3 °C). The average daily maximum UHI intensity is 4.3 °C. The strongest daily maximum UHI intensity occurs in winter with an average intensity of 6.4 °C, and the weakest one occurs in summer with an average intensity of 2.5 °C. The occurrence frequency of the daily maximum UHI intensity in the night time is 5.6 times that in the daytime [4].

We conducted based on the results and samples from air quality tracking stations around the city. In addition, the research was conducted the measurements of PM<sub>10</sub> and PM<sub>2.5</sub> at four different places, by using Dust Trak TM II 8532.

Late years, air, soil and water pollution have been adding from due to growing of population in Ulaanbaatar city.





**Figure 1.** Study area.

Many research studies a change, pollution, assessment and risk of air quality in Ulaanbaatar City. By their studies, The spatial patterns in  $\text{SO}_2$  and PM, seasonal and diurnal patterns in  $\text{PM}_{2.5}$ , and high wintertime  $\text{PM}_{2.5}/\text{PM}_{10}$  ratios were consistent with a major impact from coal and wood combustion in the city's low-income traditional housing (ger) areas. The annual average concentration of  $\text{PM}_{2.5}$  measured at a centrally located government-monitoring site was  $75\mu\text{g}/\text{m}^3$  or more than seven times the World Health Organization's  $\text{PM}_{2.5}$  air quality guideline, driven by a wintertime average concentration of  $148\mu\text{g}/\text{m}^3$ .  $\text{PM}_{2.5}$  concentrations measured in a traditional housing area were higher, with a wintertime mean  $\text{PM}_{2.5}$  concentration of  $250\mu\text{g}/\text{m}^3$  [1].

The World Health Organization (WHO) listed the air pollution in Ulaanbaatar, Mongolia among the top 5 cities with the worst air quality in the world [5].

The study concluded that mass concentration of  $\text{PM}_{2.5}$  and  $\text{PM}_{10}$  increases during winter and decreases during summer. This variation depends on climate and pollution sources [6]. In our study, we assessed an air pollution of settlement areas of Ulaanbaatar city.

## 2. Data and study method

The research regarding pollutants such as  $\text{CO}$ ,  $\text{NO}_2$ ,  $\text{SO}_2$ ,  $\text{PM}_{2.5}$ , and  $\text{PM}_{10}$  was conducted based on the results and samples from air quality tracking stations around the city. Also the research was conducted the measurements of  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  at four different places such as Sansar Tunnel, Zaisan Hill, Kyokushyu Tower, Denjiin 1000 by using Dusttrak TM II 8532 TSI (Equation 1).

$$\text{concentration} = \frac{3000 \times (\text{filter post weight} - \text{filter pre weight})}{2 \times \text{dustTrak monitor flow rate}} \times \text{total sample time (1)}$$

The concentration of an air pollutant was calculated by dividing the mass of the air pollutant collected by the volume or mass of stack gas sampled (Equation 2). Continuous emission monitoring systems (CEMS) measure gaseous air pollutants directly by fluorescence ( $\text{SO}_2$ ), infrared spectroscopy ( $\text{CO}$ ), and chemiluminescence ( $\text{NO}_x$ ). Identifies the concentrations of the criteria air pollutants typically found in stack test and CEMS results. Concentrations were reported on a mass or volume basis. The concentration of nitrogen dioxide ( $\text{NO}_2$ ) reported is assumed to be the difference between total nitrogen oxides and nitric oxide. A stream of sample air was drawn through a cell where it is exposed to pulsed ultraviolet light, resulting in excitation of sulphur dioxide molecules. These molecules subsequently re-emit light but at a different wavelength; they fluoresce. The intensity of the fluorescent light measured by a photomultiplier tube is proportional to the concentration of sulphur dioxide in the sample air.

Sample air was drawn into a cell where a beam of infrared light is passed through it to a photodetector. Some of the light has been absorbed by carbon monoxide in the sample, the amount being proportional to the number of molecules present. By comparing the light intensity received by the photodetector through the sample cell with that received through a similar cell containing reference gas, the concentration of carbon monoxide may be determined. This standard usage is assessing, monitoring the indoor and outdoor air quality in town, apartment, office, public service place, and civil building [7].

$$\text{concentration} = \frac{\text{mass of air pollutant collected}}{\text{Volume or mass of air sample}} \quad (2)$$

Illustration was made by using Interpolation method of IDW (Inverse distance weight) of ArcGIS 10.1 [2] (Equation 3). A model for pollutants plumes was designed through a GIS to calculate the dispersal of total suspended particulate (TSP) loads over the landscape and to estimate its spatial distribution and to analyse its relationship with other geographic land use attributes [3]. The GIS was used for determining the type and area of the natural landscape affected by the pollutants.

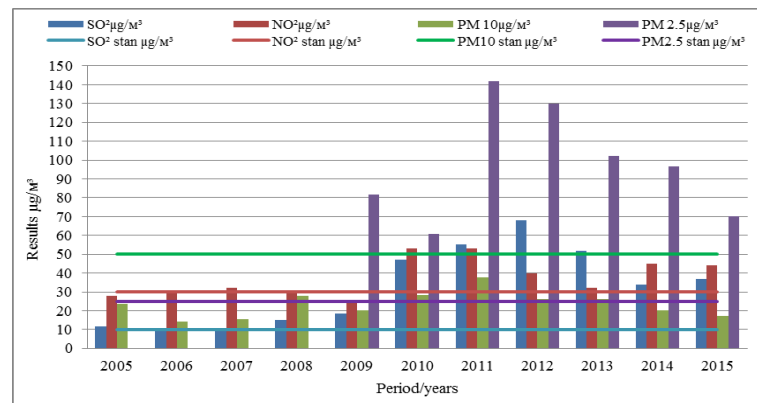
$$D = \sum_{g=1}^G d_g^{-b}, \quad \widehat{P}_0 = \frac{1}{D} * \sum_{g=1}^G d_g^{-b} * P_g \quad (3)$$

### 3. Research results

The research on air quality of Ulaanbaatar was conducted based on the facts and information we produced and information provided by the air quality tracking stations around the city.

#### 3.1. Research on air quality of ulaanbaatar and dispersion

Contents of SO<sub>2</sub>, NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> in air of Ulaanbaatar were defined by the average points provided by the air quality tracking stations (Figure 2).



**Figure 2.** Figure is content of SO<sub>2</sub>, NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub>. The average annual content of quite stable in from 2005 to 2015.

The average monthly content of NO<sub>2</sub> in 2012 was at its lowest and November and December were the highest compared to those of other years (Figure 2). Yearly diagrams demonstrate that 2011 was the lowest point whereas the content of NO<sub>2</sub> in air was increasing in 2012-2013 and started to decrease in 2014-2015. The content of SO<sub>2</sub> in air was shown in the figure that SO<sub>2</sub> started increasing from 2009 to 2012. In these years, the content of SO<sub>2</sub> in air slow increased 2009 to 2010. However it was greatly advanced content of SO<sub>2</sub> in air in 2012. The content of SO<sub>2</sub> in air was the highest in 2012 and 2010 and it was shown in the figure that SO<sub>2</sub> started increasing from 2009 and it started decreasing from 2013. In addition, figure shows that during the winters the content of SO<sub>2</sub> in air is about 1.5-1.7 times higher than the standard. The content of PM<sub>10</sub> in air in Ulaanbaatar city was higher volume contained at spring and autumn. By research, content of PM<sub>10</sub> is high from standards of Mongolia and World Health Organization in four seasons in year (Figure 2). As we can see in the figure 2, the content of PM<sub>10</sub> in air was at its peak during 2009, especially in April, May and November. The content of PM<sub>10</sub> is higher than the standard all through the year. The Content of PM<sub>2.5</sub> in air was highest in 2011, 2013 which were 3 times higher than the standard then (Figure 2).

The average monthly content in December and January has relatively high than other months of the year whereas during the summer when it has the highest level of rainfall, the content of PM<sub>2.5</sub> in air is low. Even though it was assumed that there is some seasonal impact on the content of PM<sub>2.5</sub>, the difference in average annual content is insignificantly low.

When we compared the average contents of pollutants in air of 2015 to those of 2009,  $PM_{10}$  has decreased by 15%,  $SO_2$  by 20%,  $NO_2$  by 19% respectively. During the winter of 2015, the average content of  $SO_2$  has increased by 25%,  $PM_{10}$  by 25% compared to the previous year. The  $PM_{2.5}$  has decreased by 13% compared to 2009 and relatively similar to other years.

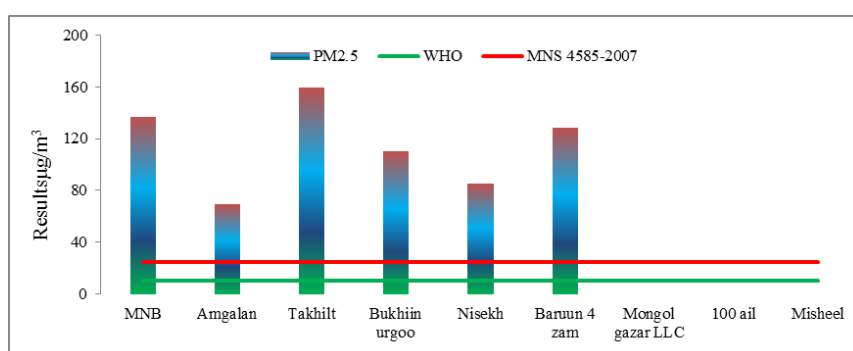
### 3.2. Illustration of air pollution dispersion

The GIS was used for determining the type and area of the natural landscape affected by the pollutants. Next part of our research, we illustrated the picture of distribution of air pollution in Ulaanbaatar city. The program automatically calculated the pollutant concentration result the all pollution, altogether, at each node of a user defined grid covering all sensitive areas vulnerable to the air pollution impact.

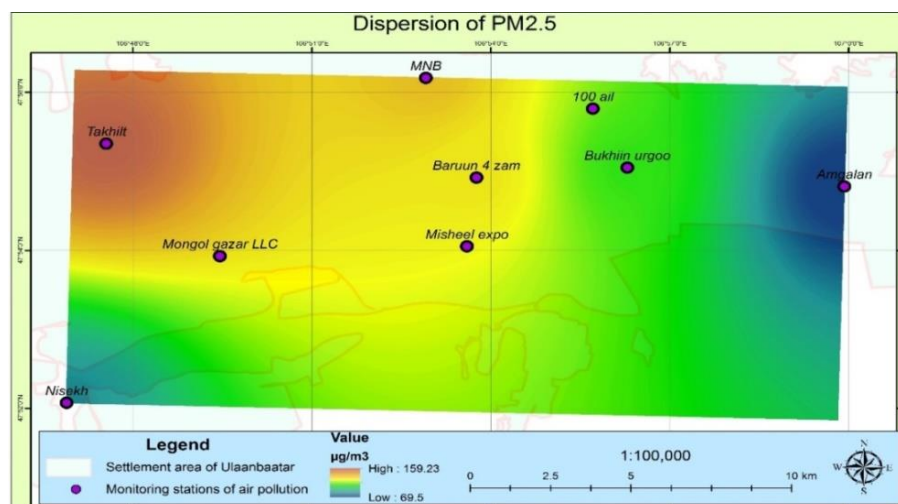
We calculated by average measurement of sample in 6 months in winter in 2015 at nine stations that sampling the air quality in Ulaanbaatar city.

The research on air quality of Ulaanbaatar city was shown below according to the air quality tracking stations and the results produced (Figure 3-6).

a)

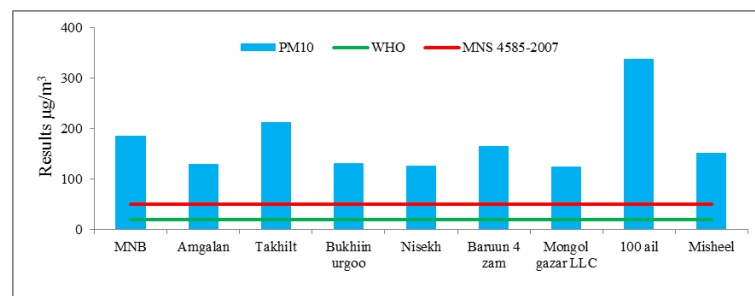


b)

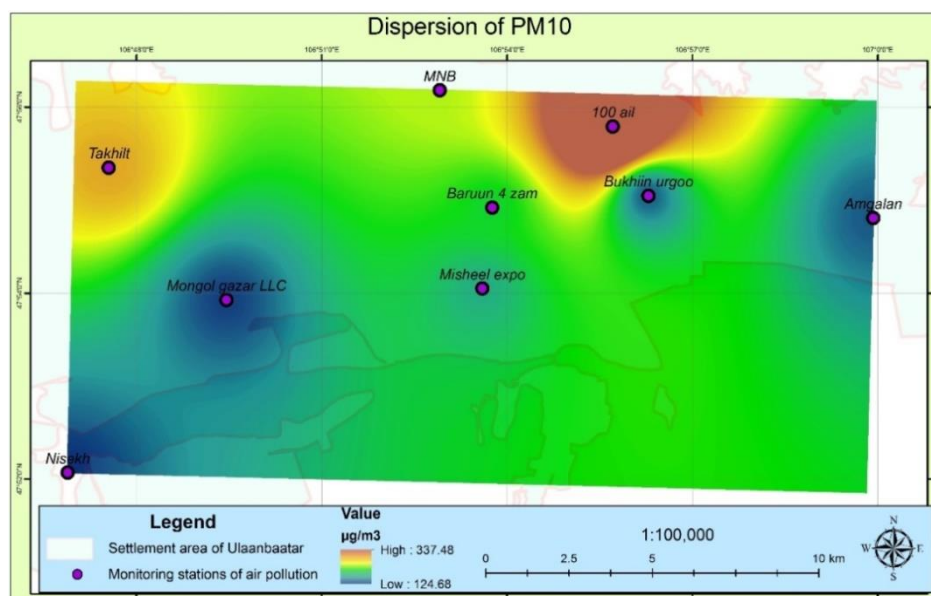


**Figure 3.** (a, b) Content of  $PM_{2.5}$  and its dispersion (by the average of 10, 11, 12 months, 2015 and 1, 2, 3 months, 2016)  $PM_{2.5}$  has been recorded to be higher than the standard at all stations. The highest level of pollution by  $PM_{2.5}$  was recorded at Takhilt station what was  $221.47 \mu\text{g}/\text{m}^3$  or 4.4 times higher than the standard as of November 2015 whereas the lowest mean was  $98.2 \mu\text{g}/\text{m}^3$  recorded at Bukhiin Urguu station.

a)

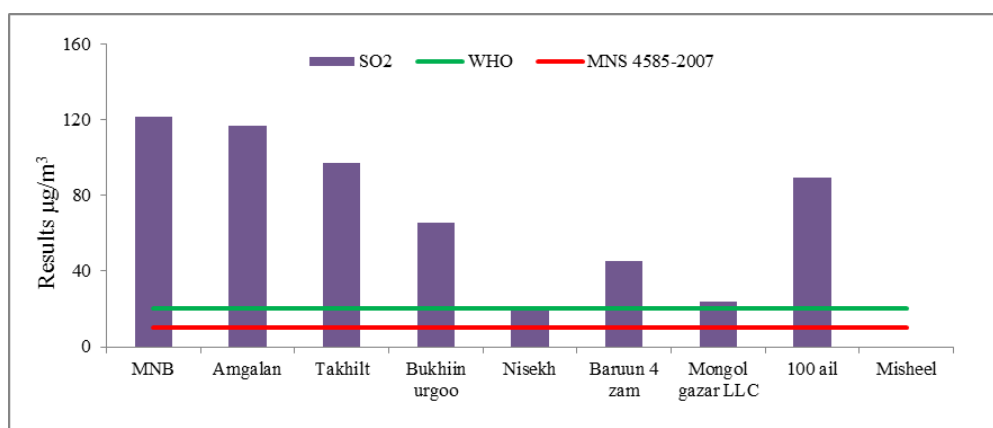


b)



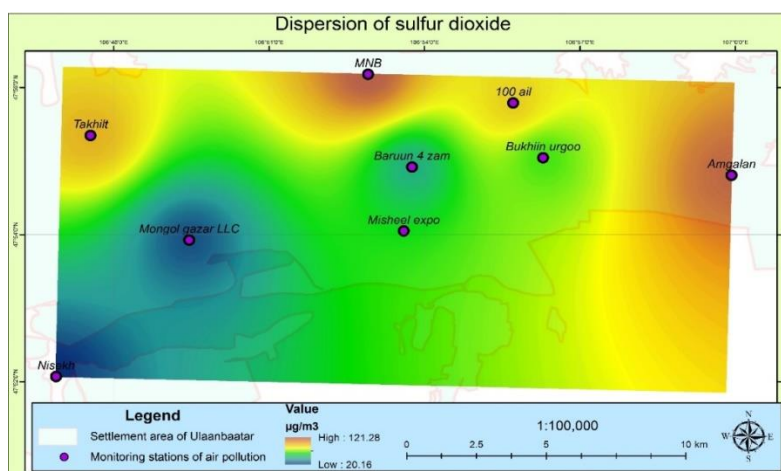
**Figure 4.** (a,b). Content of PM<sub>10</sub> (by the average of 10, 11, 12 months, 2015 and 1, 2, 3 months, 2016) PM<sub>10</sub> has been recorded to be higher than the standard at all stations. The highest level of pollution by PM<sub>10</sub> was recorded at 100 ail station, which was 291.9 µg/m<sup>3</sup> or almost 3 times higher than the standard level as of November 2015 whereas the lowest mean was 102.7 µg/m<sup>3</sup> recorded at Misheel Expo station.

a)



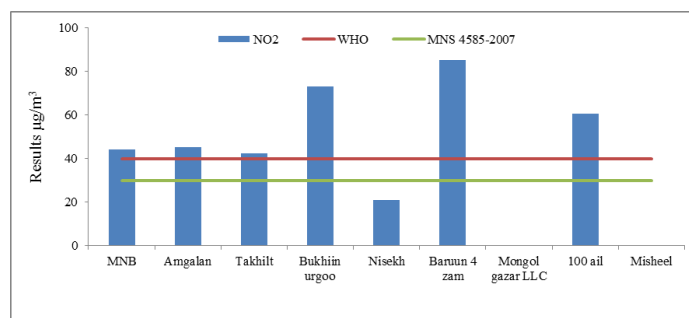


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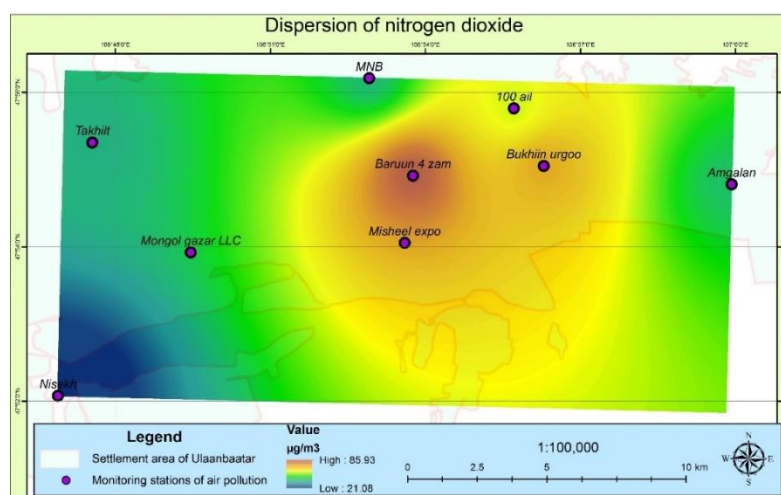


**Figure 5.** (a,b). Content of SO<sub>2</sub> in air of Ulaanbaatar (by the average of 10, 11, 12 months, 2015 and 1, 2, 3 months, 2016) Content of SO<sub>2</sub> in air of Ulaanbaatar was at the highest level at the areas around the stations Takhilt, MNB and Amgalan which were about 3 or 4 times higher than the standard level. The lowest point was recorded at the areas around Mongol Gazar LLC, Baruun 4-Zam and Nisekh, where was 25.8-34.5 µg/m<sup>3</sup>.

a)

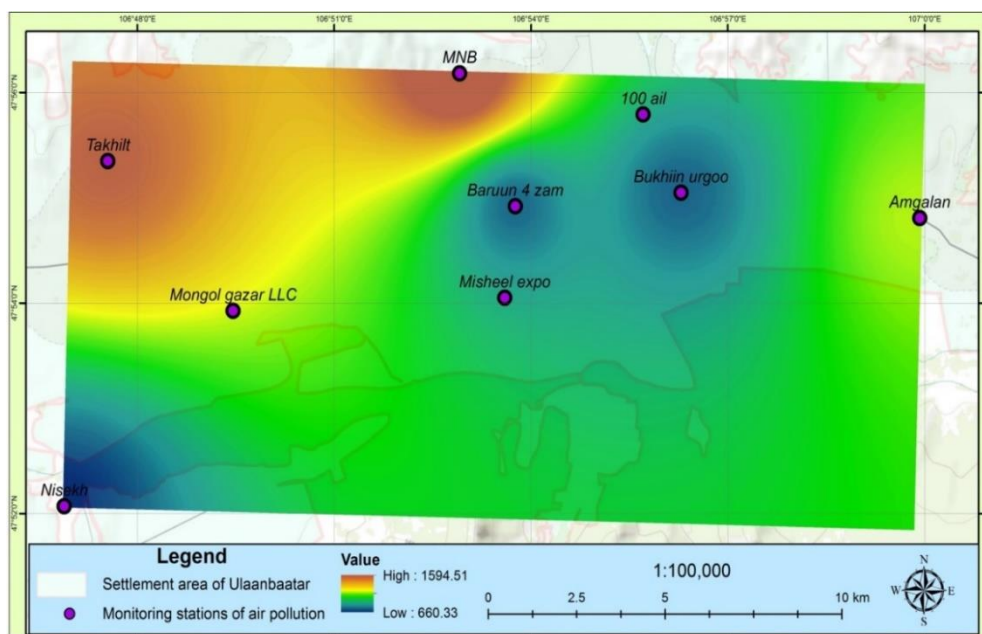


b)



**Figure 6.** (a,b). Content of NO<sub>2</sub> (by the average of 10, 11, 12 months, 2015 and 1, 2, 3 months, 2016) the content of NO<sub>2</sub> in air of Ulaanbaatar is at the highest level around Baruun 4-Zam, 100 Ail, Bukhiin Urguu and MNB which were 1.2-2 times higher than the standard level. However, Nisekh was polluted less than the other areas and the pollution level was lower than the standard level.

The highest amount of air pollutants were recorded around the western part of the city, areas such as Bayankhoshuu, 1<sup>st</sup> Khoroolol, Tolgoit and Khanyn Material. These numbers were already 2-3 times higher than “the dangerous level” according to the air quality index (AQI) of Mongolia. The areas around the city centre, Nisekh and Amgalan were relatively low in amount of air pollutants compared to the other parts of the city; those numbers were still 1-1.5 times higher than the dangerous level of AQI (Figure 7).



**Figure 7.** The combined amount of pollutants in air of Ulaanbaatar.

#### 4. Conclusion

When air pollution levels in the areas around Ulaanbaatar were measured using the results recorded at the stations, the highest pollution level was recorded during the winter of 2011 and it was shown in the research that air pollution started decreasing in 2013 and began increasing in 2015. SO<sub>2</sub>, PM<sub>10</sub>, PM<sub>2.5</sub> and CO are the dominating factors of air pollution in the outskirts of the city and the stations at Takhilt and MNB have produced the most polluted samples. NO<sub>2</sub> is the most influential pollutant around the areas of Baruun 4-Zam, 100 Ail, and 13rd khoroolol whereas Amgalan is the area least polluted by NO<sub>2</sub>. PM (Particulate Matter) is the biggest polluting factor during the winters.

When air and soil pollution levels are limited to the areas around Nisekh, Tolgoit, MNB, Amgalan, MNB areas are the most polluted in the city and Sansar Tunnel and 13rd Khoroolol are the least polluted areas whereas Tolgoit, Sapporo, 1<sup>st</sup> Khoroolol, Amgalan, Shar Khad are moderately polluted and the areas around Baruun 4-Zam, Factory, Zaisan, Nisekh are normally polluted. The results of pollution are illustrated and MNB, Bayankhoshuu and Denjiin 1000 are the first zone, Tolgoit, Baruun Salaa, Zuun Salaa, 1<sup>st</sup> Khoroolol and Sapporo are the second zone, Yaarmag, 25<sup>th</sup> Pharmacy, 10<sup>th</sup> Khoroolol and western area of Factory are the third zone and Sansar, Factory, Zaisan, and Dunjingarav are the fourth zone. By dividing the polluted areas into such zones, we are trying to make it easier to take preventive measures against the pollution itself and protective measures for safeguarding the health of mass population.

#### 5. References

- [1] Allen R W, Gombojav E, Barkhasragchaa B, Byambaa T, Lkhasuren O, Amram O, Janes C R, 2011 An assessment of air pollution and its attributable mortality in Ulaanbaatar, Mongolia. *Air Quality, Atmosphere & Health*, **6** (1), p 137–150

- [2] Curtis A. J., Mills, J. W., & Leitner, M. (2006). Spatial confidentiality and GIS: re-engineering mortality locations from published maps about Hurricane Katrina. *International Journal of Health Geographics*, 5(1), p 1–12
- [3] Fouda, Y. E. (2001). A GIS for environmental assessment of air pollution impacts on urban clusters and natural landscape at Rosetta City and region, Egypt. *Urban Ecosystems*, 5(1), p 5–25.
- [4] Ganbat, G., Han, J.-Y., Ryu, Y.-H., & Baik, J.-J. (2013). Characteristics of the urban heat island in a high-altitude metropolitan city, Ulaanbaatar, Mongolia. *Asia-Pacific Journal of Atmospheric Sciences*, 49(4), p 535–541
- [5] Guttikunda, S. K., Lodoysamba, S., Bulgansaikhan, B., & Dashdondog, B. (2013). Particulate pollution in Ulaanbaatar, Mongolia. *Air Quality, Atmosphere & Health*, 6(3), p 589–601.
- [6] Sonomdagva, C., Batdelger, B., & Byambatseren, C. (2016). Characteristics of PM<sub>10</sub> and PM<sub>2.5</sub> in the Ambient Air Ulaanbaatar, Mongolia. *Environmental Science and Development*, Vol 7, p 827–830
- [7] “Mongolian National Standard 4585; 2007

## 6. Acknowledgements

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