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PARTICULATE DISPERSION MODELING OF SALT HARVESTING ACTIVITIES FROM LAKE URMIA

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ABSTRACT:

Introduction: Drying of parts of Lake Urmia has exposed to salt domes in various areas of the lake. As such, the economic incentive for salt harvesting has been improved due to the easier access. Nonetheless, these operations have the potential of generating particulate air pollutants that can adversely impact immediate and distant agricultural and residential areas. Dispersion modeling is needed to evaluate the effect of various operational parameters on the generation and transport of these particulates.

Materials and methods: A mine with the capacity of 1250 tons /day in the area of Qobadlu and two other salt sites around lake Urmia were considered for modeling. Major activities that contribute to pollutant production include transport vehicles and wind erosion from storage salt piles. Wind erosion from the piles was evaluated under different scenarios using CFD approach. Using emission factors for other activities, topographic and climate data, Gaussian dispersion of particles was conducted using ADMS modelling system.

Results: The results showed that transportation of particles occurs towards the lake with negligible concentrations for distances within the 150 m radius; observed trend was a reduction from concentrations of around 100 µg / m^3 at the site to 5 µg / m^3 at the afore - mentioned distance. Layout optimization of storage piles and erection of barriers respectively resulted in up to 17 % and 44 % reduction in particulate generation from pile surfaces.

Conclusions: The results of this research have been used in the preparation of the environmental guidelines for salt harvesting in compliance with the lake Urmia restoration directives.

INTRODUCTION

The release and dispersion of dust particles due to the industrial activities can have adverse impact on human health and can cause damage to agricultural productivity. In assessing the environmental impacts and determining the extent and distribution of suspended particles' transport potential due to salt extraction activities from Lake Urmia, spatial and temporal aspects need to be taken into account. These include parameters such as site of activity, volume of harvest, transportation route of trucks, and the climate conditions. Loading at the receptor can be estimated from the extent of wind erosion on the salt piles, atmospheric dispersion, and surface deposition.

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Models for particle concentration simulation are derived from the combination of dynamic modules of aerosols with dispersion models. According to a study which was conducted on winds on the lake Urmia Basin using the TAPM model [1]. In another study it has examined the numerical models of EURAD and WRF/Chem in the prediction of dust in five stations, including Urmia [2]. Other researchers examined the release of salt particles into the surrounding environment due to the drying of lake Urmia; their results show that the southern, eastern, and northeastern parts adjacent to the lake are the most susceptible areas [3]. In a research, it has also examined 30 software models considering their various capabilities in simulating particle propagation; final recommendation is the use of Urban ADMS modelling system [4]. In another study, it was examined the effect of the arrangement and form of accumulation piles in open yards in particle distribution [5].
ANSYS Fluent and ADMS were used for modeling in this study, and the output of these models will be evaluated.

MATERIALS AND METHODS

Salt extraction takes place in a mine with a capacity of 1,250 tons / day, which equates to the traffic of about 50 eighteen-wheeler-trucks with an average load of 27.5 tons. In Fig. 1, the study area is located on the beach of the village of Qobadlu, where salt extraction is currently exercised. Salt storage area, trucks' route, and proper harvesting locations have been considered as candidate particle generation sites.

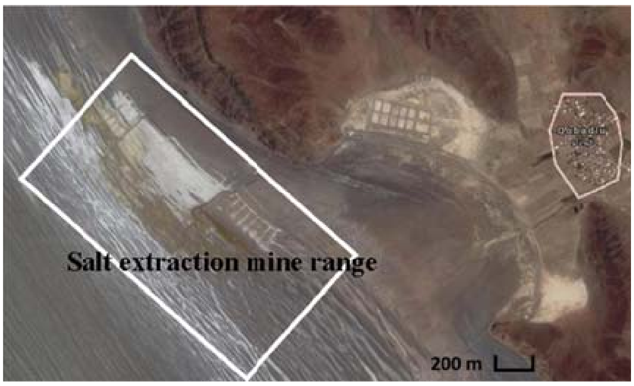

Fig. 1. The mine area studied at Qobadlu beach

CFD modelling approach provides a complex analysis of the fluid flow based on mass and momentum survival by solving the Navier - Stokes equation by finite difference method and finite volume methods in three dimensions. The turbulence is classically calculated using k-ε method for the isotropic eddy viscosity parameter that is present in the momentum equations and the transmission of pollution. In the ADMS model, thermodynamic parameters, chemical properties, heat transfer, and aerosol load are included in the considerations. This is an advanced integrated modelling system for calculation of concentrations from continuous plumes of point, linear, volumetric and area sources. First, the particle emissions from salt-related activities, including truck traffic, accumulation and harvesting, as well as salt piles, are determined by empirical relationships and existing standards, as well as CFD simulation. In this regard, the various modes of creating a pile in such a way as to produce lower emission values are also analyzed. Meteorological and topographic data as well as particle emission data were used as input to the ADMS Gaussian calculation model, and dispersion was calculated under different scenarios at various distances and directions from the salt harvesting site.

RESULTS AND DISCUSSION

Emission factor calculations

Truck Traffic: In order to determine the particle emission factor from the unpaved roads, considering the volume of materials that are transported averaged over a day by trucks and taking into account the average weight of trucks in transit, using the Eq. (1), the emission factor is calculated for each meter of the road [6, 7]:

$$E = k\,(s / 12)^{a}\,(W / 3)^{b} \qquad (1)$$

Where;
E: size - specific emission factor (lb / VMT)
W: mean vehicle weight (tons)
s: surface material silt content (%)
k, a, b empirical constants according to the corresponding tables

Also based on reference [6], the following values are considered in the calculations:
k= 1.5
a= 0.9
b= 0.45
s: silt percentage is 10% [8]
To convert the amount of emission factor obtained from the above equation to the metric unit, we use Eq. (2):

$$1 \text{ lb / VMT} = 281.9 \text{ g / VKT} \quad (2)$$

In other words, each pound per vehicle mile traveled is equal to 281.9 g / km. The calculations for determining the emission factor of trailer traffic in a given salt mine are given in Table 1. In this case, it is assumed that for carrying materials, an 18 - wheeler trailer is used so that the weight of the trailer with a load is 40 tons and without load is assumed to be 15 tons, which is the average of these two values due to the movement of full trailer and empty is estimated at 27.5 tons [9].
Loading and load out of aggregate: the production of dust particles in the storage cycle can occur, such as the loss of material during the formation of the pile, harvest handling from the pile and unloading of the vehicle carrying materials.
The amount of particulate emissions produced by the above activities can be calculated from Eq. (3) [10]:

$$E = k(0.0016)\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \quad (3)$$

E: emission factor (kg / ton)
k: particle size multiplier (dimensionless) equal to 0.35
U: mean wind speed (m / s)
M: material moisture content (%)

Stacks (Pile) of salt accumulation: amount of particulate emission from piles depends on various factors including the shape, orientation, existence of barrier, etc. [11]. For comparison between various types of piles, the same amount of the material into various shapes of piles must be modeled. The extent of particle generation and transport, is used as a criterion for utility of pile geometry. Four different forms of these stacks were considered:
1 - One conical pile with capacity of 181.4 tons of salt has the diameter and height of 11.99 and 3.81 meters, respectively.
2 - Two conical piles with capacity of 90.7 tons

Table 1. The calculations of emission factors in the movement of trucks

Title	Calculations
Average weight of trucks (Load and unload) (ton)	27.5
Length of roads (m)	1500
Amount of displaced material (ton)	1250
The number of transport trucks	50
The average number of trucks per hour	2.08
Distance traveled per day (km)	150
Emission factor (g / VKT)	973
Emission factor of the whole road (g / s)	0.84424

Table 2. Calculations of emission factors by accumulation and withdrawal

Amount of material handled per day (ton)	Average speed m/s	Relative humidity %	Emission factor Kg / ton	Emission factor g / s
1250	2.21	0.22-4.8	0.00282	0.0815

per each pile. Diameter of pile is 9.5 m and height is 3.05 meters.
3 - One linear pile with the capacity of 181.4 tones. Pile length, diameter and height equal to 7, 7.6 and 55.2 m respectively.
4 - One linear pile that its upper surface is triangular instead of a circular form. Capacity of this pile is the same as the previous types, i.e. 181.4 tons.
In the Table 3, the outer surface area of each pile is calculated.
Using computational fluid dynamics software requires meshing over the entire geometry, then setting the resolution parameters. These parameters include boundary conditions, initial conditions, type of solvent, disintegration order, turbulence model, solvent accuracy, and so on. Boundary conditions have been allocated as it can be seen in Fig. 3.
The contour of the velocity distribution from the Fluent software for the pile under study was analyzed and in Table 4. The maximum speed for each type of pile is calculated.
In order to investigate the effect of barrier, a barrier with a height of one meter and one meter distance from the pile of the four mentioned above, was erected and modeling was conducted.
For better comparisons, velocity profiles on the surface of pile in two conditions of the lack and existence of barriers were superimposed and are shown below (No. 1 pile as an example). The average speed for each of these surfaces is also compared in Table 5.

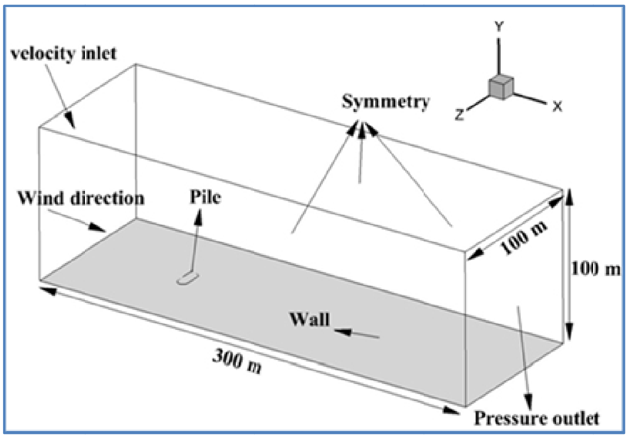

Fig. 3. Boundary conditions used to solve the problem

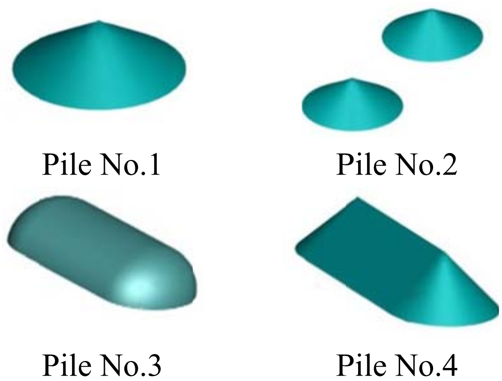

Fig. 2. Different forms of salt piles

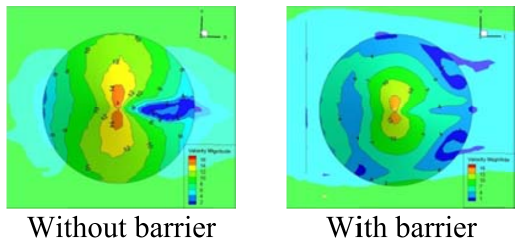

Fig. 4. Speed profile on pile No. 1 (with and without barrier)

Table 3. Surface area outside of salt piles

Number of pile	1	2	3	4
Surface area (m²)	133.8	168.5	115.6	138.2

Table 5. Comparison of speeds on piles with and without barrier

Number of pile	Average speed (m / s)		Difference percentage
	Without barrier	With barrier	
1	9.0466	5.0466	44
2	9.1141	6.9996	23
3	9.4795	6.1582	35
4	5.8909	4.6539	20

Table 4. Maximum surface velocity on piles

No. of pile	1	2	3	4
Max. vel. on pile (m / s)	17.7	16.6	16.2	15.6

It can be seen that the average speed on the pile surface with a one meter high barrier behind, it is much less than the pile that is exposed directly to the wind, which will result in lower wind erosion rates.

Meteorological information

In practice, the best time for salt extraction operation is summer and fall. In this study, meteorological data of three cities around Lake Urmia have been used, i.e. AjabShir, Urmia and Salamas.
More important meteorological data used in this study including wind speed and direction, also information such as rainfall, humidity, temperature and cloudiness have been used in the investigation and modeling.
It can be seen that for Salmas (lake north - west) prevailing and semi-prevailing wind direction from North to South and from West to East, for Salamas (lake east) prevailing winds blowing from east to west and from the southeast to the northwest is the semi - prevailing, also for Urmia (lake west) prevailing wind is from the West to the East. Due to the placement of these three cities relative to the lake, it seems predominant wind direction in the summer and fall is toward to the lake.

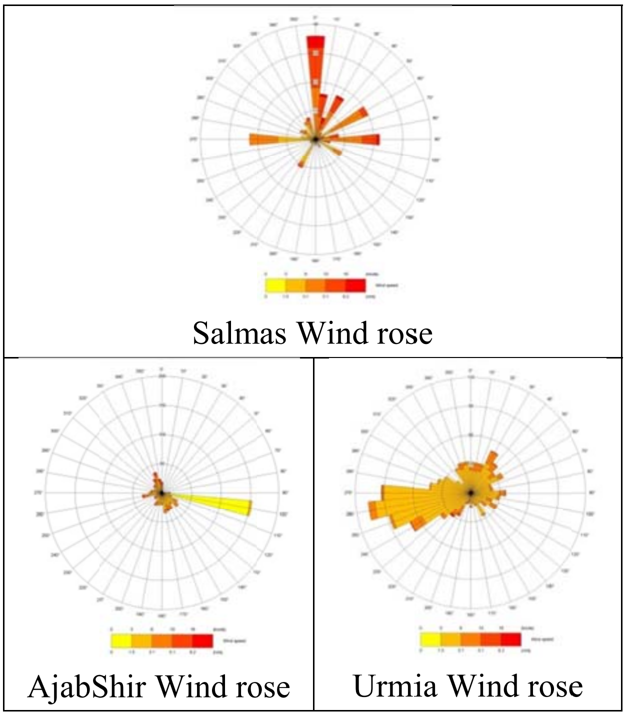

Fig. 5. Summer and fall (2014) wind rose

Topographic information

Topographical data contains information about terrains around the lake. Area examined in this study, in the southeast, west and north West Lake is shown in Fig. 6.
For each region, particle modeling has been done, using a salt extraction of the same specification and topography data of that area and information based on the nearest weather station.

Particle dispersion modeling

Results obtained from ADMS software modeling have been shown using Surfer software as particle distribution contour that coincident with the area of the study.
Modeling of Qobadlu beach: nearest synoptic station to this area is located in AjabShir city. This area is one of the places that was already extracting salt and with regard to existing roads, well access is achieved. The coordinates of the study area are given in Table 6.

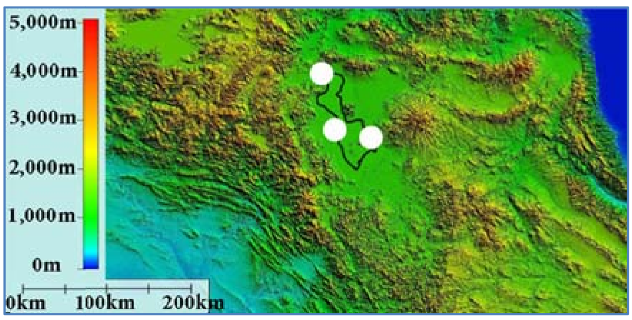

Fig. 6. Terrain around the lake
(range studied marked with white circles)

Table 6. Coordinates of the desired range on the Qobadlu beach

Coordinates	min	max	zone
X	562908	565908	38 S
Y	4153955	4156955	

Particle dispersion in this area is shown in the Fig.7

It can be seen in the Qobadlu beach area the distribution of particles is extended toward the lake in the summer and fall. In other words, the particles emitted by salt extraction process in this area will be scattered to the West and North West.

It is also observed that, by getting away from the source of particulate emissions, the concentration of suspended particles in the air quickly reduced, as in the distance of 100 to 200 m from the salt harvesting, concentration of pollutant reduces to below of 5 μg / m^3

Modeling of Urmia city beach: Urmia city is located in the west of lake Urmia. In the coastal area near the city of Urmia, a hypothetical range of salt extraction is considered. The coordinates of the study area are given in Table 7.

The result of the particle distribution modeling for the summer and fall of 2014 is presented in Fig. 8

Within the Urmia city beach, particulate emissions in summer and autumn expanded eastward (toward the lake), as can be seen, particulate emissions toward land is low so that the amount of particle concentration is very low in a very short distance from the salt extraction range on the land side (about 100 to 150 m).

Modeling the northwest lake area (north of the Qara Bagh village): for the modeling of how the particles of salt extraction are distributed around the lake, the northwestern lake located north of the village of Qarabagh has also been studied and meteorological data from Salmas station has been used. The coordinates of the study area are given in Table 8.

In Fig. 9, the result of particle distribution modeling in the northwestern beach of lake Urmia (north of the Qarabagh village) for summer and autumn is presented.

According to the obtained diagram, it can be seen that the particle emission on the northern beach of Qarabagh village (northwest of Lake Urmia) is more eastward and later to the south, which considering the intended location, the particles are dispersed towards the lake.

Fig. 7. Particle dispersion at Qobadlu beach

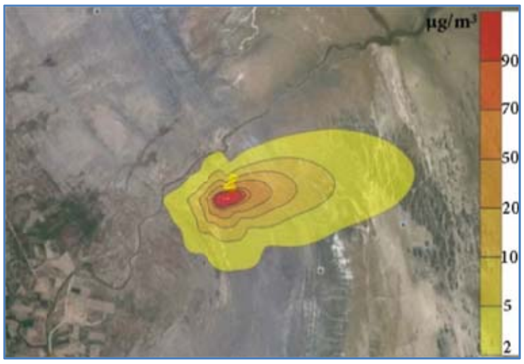

Fig. 8. Particle dispersion at Urmia city beach

Fig. 9. Particle dispersion in the north beach of Qarabagh village

Table 7. The coordinates of the desired range on the Urmia city beach

Coordinates	Min	max	zone
X	523820	526819	38 S
Y	4156136	4159128	

Table 8. The coordinates of the desired area on the northwest coast of Lake Urmia (north of Qarabagh village)

Coordinates	min	max	zone
X	503108	507108	38 S
Y	4217826	4221826	

CONCLUSIONS

Using Fluid modeling and Gaussian particle dispersion modeling for different states and different situations, resulted in information that provide the basis for study on environmental impacts of the salt extraction. Considering the location of the Urmia city in the west of the lake and the extent of agricultural areas in the south and west regions of lake Urmia, the measurement of the amount of particulate emissions in these areas during the salt harvesting is necessary. In addition, taking into account the distance of Tabriz from Lake Urmia, particles released from salt extraction will have no effect on this city. According to the results obtained from the analysis of the piles, it is concluded that the salt harvesting range should be determined in such a way as to have the smallest dimensions in the direction of the dominant wind, as well as larger dimension and fewer piles to reduce wind erosion. This will result in a forty-four percent reduction in particle emissions from the surface of the piles. Considering the results of particle distribution modeling, the shelter range of salt extraction is recommended to be 150 m.

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COMPETING INTERESTS

The authors declare that they have no conflict of interest.

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ETHICAL CONSIDERATIONS

The authors state that they have no ethical considerations.

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