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Potential Effects on Human Health of Hydrogen Sulfide Exposure in a Place in Southeast of Mexico

Manuel Muriel-García[1], Rosa María Cerón-Bretón[2], Julia Griselda Cerón-Bretón[2]

[1]Instituto Mexicano del Petróleo, Ciudad del Carmen, México
[2]Facultad de Quimica, Universidad Autónoma del Carmen, Ciudad del Carmen, México
Email: jceronbreton@pampano.unacar.mx

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Abstract

Ambient concentrations of H_2S were determined by modeling the H_2S emissions dispersion for three sites located in the surroundings of oil and gas maritime terminal at the southeast of Mexico. Hazard quotient is reported for different age groups. Paraiso City in Tabasco State reported the highest values for over 19 years old group (0.49). It was concluded that there was no threat to human health due to H_2S emissions derived from the maritime terminal for the studied sites.

Keywords

Risk assessment, H_2S, Air Pollution, Southeast of Mexico

1. Introduction

Some communities have expressed health concerns over low-level exposure to hydrogen sulfide (H_2S) [1]). In the past years, several efforts such as long-term air monitoring to establish patterns or changes of environmental exposures, improve validity and representativeness of data, and prevent exposure misclassification [2] taking place. Campagna and co-workers findings are consistent with the hypothesis that exposure to malodorous sulfur compounds increases the risk of respiratory problems and symptoms. They suggest that ambient levels of H_2S may have been associated with exacerbations of asthma or other respiratory diseases among residents of Dakota City and South Sioux City during 1998-2000 [3].

Recently, Jeffrey explains that respiratory symptoms are the most frequently increased endpoint among both children and adults exposed to chronic low-level (~<10 ppm) H_2S exposure from both anthropogenic and natu-

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ral sources. They conclude that such effect appears to be temporary, given that there is no consistent evidence of pulmonary function deficits in either age group among those chronically exposed to low H_2S concentrations. It is also indicated that “findings of respiratory symptoms may be the result of selective recall or an agitation effect from the pungent odor produced by H_2S” [4].

Environmental Protection Agency established an inhalation reference concentration (RfC) by dividing the No-observed-adverse-effect level adjusted for dosimetric differences across species to a human equivalent concentration. (NOAEL) HEC for nasal effects by the Uncertainty factors (UF) of 300 yields an inhalation RfC of 0.002 mg/m^3 [5]. Inhalation Reference Concentration (RfC) is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis. The inhalation RfC considers toxic effects for both the respiratory system (portal-of-entry) and for effects peripheral to the respiratory system (extra respiratory effects). The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily inhalation exposure of the human population (including sensitive subgroups) [5].

In this paper, we address the concerns of communities in the southeast of Mexico (see **Figure 1**), which have been exposed to low levels of H_2S. We determined ambient concentrations of H_2S by modeling the H_2S emissions dispersion. Results were combined with a specific questionnaire to exposed population. Finally, a hazard quotient is obtained for different age groups. The purpose of the current health investigation is to determine whether general population has experienced a chronic exposure to H_2S, demonstrate a possible pollution problem in this geographic area and to fill an important data gap regarding the health effects of H_2S in the ambient.

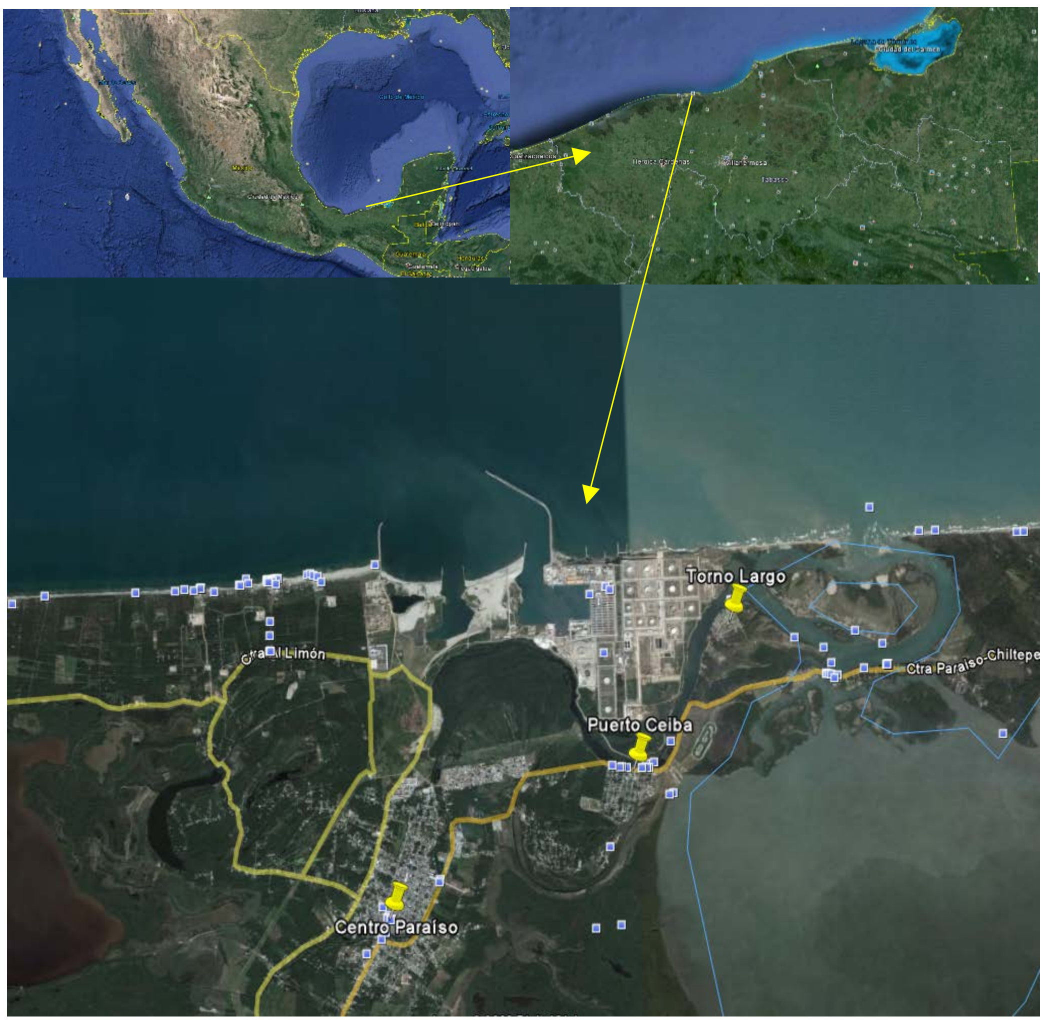

Figure 1. Geographic position of selected receptors.

Study Area

Paraíso town is a municipality located in the north of the State of Tabasco in Mexico, about 75 km at north of the state capital. Main economic activities are fishing and agriculture, and currently, it is also an important oil producing area in the port of Dos Bocas.

The land is part of the Tabasco floodplain on the Gulf of Mexico with an average elevation of only two meters above sea level. The soil is sandy with some clay mixed nearest the ocean with clay dominating inland. This area has abundant surface water in the forms of lagoons, lakes, estuaries and wetlands. Major bodies of water include lakes and lagoons such as Mecoacán, La Machona, Tupilco, Puente de Ostión, La Encerrada (Amatillo), Tres Palmas, El Zorro, Arrastradero, Las Flores, Lagartera Tilapa, Manatí and El Eslabón.

Surface water flow in the municipality is split into east and west, both connected by the Río Seco River and the Jobo Canal. The east is dominated by the Mecoacán lagoon which opens into the Gulf of Mexico at Dos Bocas. Linked to it are smaller lagoons such as the Eslabón, La Tinaja and El Carmen.

The climate is hot and wet with rains during the summer/fall with an average annual rainfall of 1751.4 mm. The coldest months are November, December and January with average temperatures around 22˚C. The hottest month is May with average temperatures around 30˚C. The windiest months are October, November and December when winds can reach 30 km/hr.

This area has perennial rainforest with trees between fifteen and thirty meters tall. However, most of these areas are disturbed. In the low ocean front areas there are beaches and mangroves. There is the occasional nopal cactus. Wildlife is mostly limited to bird and reptile species such as storks, kingfishers, seagulls, buzzards, marine and freshwater turtles, and various small lizards.

2. Methods

2.1. H_2S Emissions

A set of representative sampling points over all effluent treatment plant were designed for sampling the oil dehydration residual water, during the period of December 2008 to January 2009. Main considered components were: regulating sump, Archimedes water pump, API separator and regulating pond. Sampling consisted of 1 l of residual water in each sampling point. H_2S emissions concentration were established analyzing oil dehydration residual water Experimental values were used to feed WATER 9 V3 model process [6]. The basic equation for models that predict emissions from water surfaces, employ the following equation

$$Ea = KAMC$$

where

Ea = atmospheric emissions in g/s.

K = Mass transfer coefficient in m/s.

A = area in square meters.

M = molecular weight of the liquid phase in g/mol.

C = compound molar concentration in the liquid phase in mol/m^3.

WATER 9 model solves this equation for each part of the process to obtain final result (see **Table 1**).

2.2. Modeling

Meteorological information was produced using RAMS model with three nested grids that were spaced 40, 10 and 1 km, respectively. External grid included Gulf of Mexico and part of Pacific Ocean, while internal one covers an area of 35 × 30 km around Dos Bocas Maritime Terminal (DBMT) (see **Figure 2**).

Some of the parameters considered are:

- Constant rugosity over all domain, 0.05 meters.
- Albedo constant: 0.15.
- Constant water surface temperature: 290˚K.
- Topography resolution less than 1 km (30 seconds).
- Climatological temperature equal to sea temperature.

One meteorological scenario representing average conditions was chosen, based on a meteorological analysis of 2005-2007 data. A second one, representing critical conditions was determined upon less favorable meteorological conditions for dispersion.

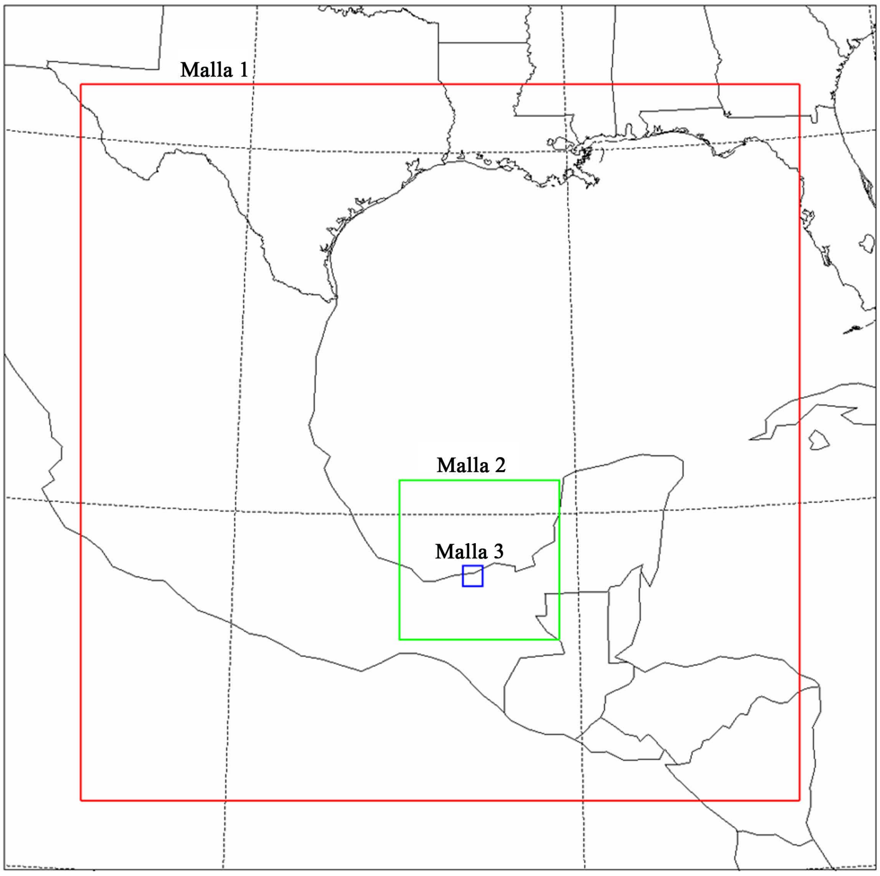

Figure 2. Nested grids for RAMS model.

Table 1. H_2S emissions.

	g/s	ton/day
Average	4.50	0.39
Maximum	10.90	0.94
Minimum	0.85	0.07

After simulating the two meteorological scenarios, CALRAMS was used to extract required variables for CALPUFF model.

Dispersion modeling was performed with CALPUFF, considering maximum and average H_2S emissions. Three receptors were considered of particular significance, Paraíso and Puerto Ceiba (see **Table 2**).

Emissions dispersion modeling on meteorological scenario representing average conditions did not produce any considerable H_2S concentration on selected receptors. On the other hand, emissions dispersion modeling on scenario representing less favorable meteorological conditions did produce significant amounts of H_2S in selected receptors (**Table 3**), specifically in Paraíso and Puerto Ceiba.

2.3. Exposure Assessment

A probabilistic approach to estimate the potential for non-carcinogenic health effects it is not used. Instead, the potential for no carcinogenic effects is evaluated by comparing an exposure level over a specified time period (e.g., lifetime) with a reference dose derived for a similar exposure period [7]. This ratio of exposure to toxicity is called Noncancer Hazard Quotient (NHQ):

$$\text{NHQ} = E/RfD$$

where:

E = exposure level (or intake);
RfD = reference dose.
E and *RfD* are expressed in the same units and represent the same exposure period (i.e., chronic, sub chronic, or shorter-term).

Exposure was obtained applying a questionnaire to inhabitants of Paraiso, Puerto Ceiba and Torno Largo. Questionnaire activities took place from November 20, 2008 to February 2, 2009. It requested for amount of time (hr.), kind of outdoor specific activities for each family member and frequency. Another demanded information included:

- Place of living,
- Age (years),
- Weight (kg),
- Residence time (years),
- Working place,
- Spent time on outdoor activities.

3. Results

Outdoor spent time was obtained adding up the amount of time of every outdoor specific activities multiplied by the frequency and for 52, for each individual and each age group. Outdoor spent time results for 680 questioned people are shown in **Table 4**, and inhalation rate for the same group are in the **Table 5**. These results were combined with dispersion modeling to get Noncancer Hazard Quotient.

NHQ results are shown in **Table 6** and **Table 7**. It is important to notice that Hazard is present only for Paraíso inhabitants and considering that H_2S air concentration is the maximum.

4. Discussion and Conclusions

It is important to mention that maximum H_2S concentration is present 26 % of the time, so to be realistic we have to consider a weighted scenario. **Table 8** describes corrected NHQ (NHQ_c) values. NHQ_c highest values are found in Paraíso for over 19 years old group, 0.49. Additionally, it can be mentioned that NHQ might be overestimated due to a lack of inclusion of H_2S decaying rate in dispersion calculations. At this stage of knowledge, it can be concluded that there is no threat to human health due to the H_2S emission of DBMT, since all NHQ values are below 1 in all three most populated places surrounding maritime terminal.

Although this result is not worrying, attention should be paid to specific effects in age groups. Children and adults exposed to chronic low-level might have an increase in respiratory symptoms [4]. It is also worthy to emphasize that no measurement for H_2S is available, neither epidemiological studies to make a conclusive to properly assess health hazard among population surrounding DBMT. It should be remembered, as with many other substances, that H_2S reference dose is based mostly on toxicological studies in animals and on limited evidence regarding health effects in humans.

Table 2. Receptors and geographic position.

Receptor	Latitude	Longitude	UTM E (Km)	UTM N (Km)
Paraíso	18˚23'44.06"N	93˚12'52.21"W	477.343	2033.964
Puerto Ceiba	18˚24'48.53"N	93˚10'41.39"W	481.184	2035.942
Torno Largo	18˚25'56.03"N	93˚9'47.64"W	482.762	2038.015

Table 3. Average 24 hrs. H_2S concentrations (μg/m^3) for less favorable meteorological conditions.

Receptor	Average emission simulation			Maximum emissions simulation		
	02-Sep-06	03-Sep-06	04-Sep-06	02-Sep-06	03-Sep-06	04-Sep-06
Paraíso	376	644	30	192	328	14
Puerto Ceiba	148	1	144	76	0	73
Torno Largo	1	0	0	0	0	0

Table 4. Outdoor spent time.

Age group	Age (years)	Weight (Kg)	Residence time (years)	Outdoor time (days/year)
Adult (>19 years)	37.65	69.24	29.20	68.90
Young (15 - 18 years)	16.71	59.50	15.48	52.12
Young (12 - 14 years)	13.26	47.13	12.64	60.00
Children (9 - 11 years)	9.83	37.53	9.25	39.24
Children (6 - 8 years)	6.98	26.83	6.63	43.39
Children (3 - 5 years)	4.00	18.28	3.83	36.61
Infant (1 - 2 years)	1.59	12.00	1.59	31.29
Infant (<1 year)	0.40	6.29	0.40	22.60

Table 5. Inhalation rate by age group.

Age group	Daily inhalation rate indoors (m^3/day)	Daily inhalation rate outdoors (m^3/day)	Number of persons
Adult (>19 years)	15.2^+	15.2^+	410
Young (15 - 18 years)	17.0^+	17.0^+	56
Young (12 - 14 years)	15.0^+	15.0^+	39
Childern (9 - 11 years)	14.0	14.0	40
Childern (6 - 8 years)	10.0	10.0	48
Childern (3 - 5 years)	8.3	8.3	48
Infant (1 - 2 years)	6.8	6.8	32
Infant (<1 year)	4.5	4.5	7
Total			**680**

Table 6. Paraiso's NHQ results.

NHQ	E (μg/m^3)	RfD (μg/m^3)	Place	Group age
0.08	0.2	2.1	Paraíso	<1
0.26	0.6	2.1	Paraíso	1 a 2
0.50	1.1	2.1	Paraíso	3 a 5
0.71	1.5	2.1	Paraíso	6 a 8
1.00	2.1	2.1	Paraíso	9 a11
1.15	2.5	2.1	Paraíso	12 a 14
1.27	2.7	2.1	Paraíso	15 a 18
1.84	3.9	2.1	Paraíso	>19

Table 7. NHQ results for Puerto Ceiba and Torno Largo.

NHQ	E (μg/m³)	RfD (μg/m³)	Place	Group age
0.02	0.0	2.1	Puerto Ceiba	<1
0.07	0.2	2.1	Puerto Ceiba	1 a 2
0.14	0.3	2.1	Puerto Ceiba	3 a 5
0.20	0.4	2.1	Puerto Ceiba	6 a 8
0.28	0.6	2.1	Puerto Ceiba	9 a11
0.32	0.7	2.1	Puerto Ceiba	12 a 14
0.36	0.8	2.1	Puerto Ceiba	15 a 18
0.52	1.1	2.1	Puerto Ceiba	>19
0.00	0.0	2.1	Torno Largo	<1
0.00	0.0	2.1	Torno Largo	1 a 2
0.00	0.0	2.1	Torno Largo	3 a 5
0.01	0.0	2.1	Torno Largo	6 a 8
0.01	0.0	2.1	Torno Largo	9 a11
0.01	0.0	2.1	Torno Largo	12 a 14
0.01	0.0	2.1	Torno Largo	15 a 18
0.01	0.0	2.1	Torno Largo	>19

Table 8. Corrected NHQ results.

NHQ_C	Place	Group age
0.02	Paraíso	<1
0.07	Paraíso	1 a 2
0.13	Paraíso	3 a 5
0.19	Paraíso	6 a 8
0.27	Paraíso	9 a11
0.31	Paraíso	12 a 14
0.34	Paraíso	15 a 18
0.49	Paraíso	>19

It would be suitable to establish an appropriate risk level based on a reliable body of evidence from epidemiological studies of population exposed to lower levels of H_2S.

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