HUMAN HEALTH COST OF HYDROGEN SULFIDE AIR POLLUTION FROM AN OIL AND GAS FIELD

D.U. Kenessary*, U.I. Kenessariyev, A.U. Kenessary

Kazakh National Medical University, Almaty, Republic of Kazakhstan

Dinara Kenessary
PhD in Public health
dku999@mail.ru

ABSTRACT

Introduction and objective: The Karachaganak oil and gas condensate field (KOGCF) is one of the largest in the world, located in the Republic of Kazakhstan (RoK),Central Asia, and is surrounded by 10 settlements with total population of 9,000 people. Approximately 73% of this population constantly mention a specific rotten eggs odor in the air that is typical for hydrogen sulfide emissions and the occurrence of low-level concentrations of hydrogen sulfide around certain industrial installations (ex.: oil refineries) is a well known fact. Therefore human health impact, as well as economic damage to the country due to H_2S emissions were determined.

Materials and methods: Dose-response dependency between H_2S concentrations in the air and cardiovascular morbidity using multiple regression analysis was applied in this research. Economic damage from morbidity was derived with a newly developed method with Kazakhstani peculiarities taken into account.

Results: Hydrogen sulfide air pollution due to the KOGCF activity cost the state almost $60,000 per year. Moreover, this is the reason for over 40% rise of cardiovascular morbidity in the region.

Conclusion: The reduction of hydrogen sulfide emissions into the air is recommended, as well as successive constant ambient air monitoring in future. Economic damage evaluation should be made mandatory, on a legal basis, whenever an industrial facility operations result in associated air pollution.

KEYWORDS — hydrogen sulfide, human health, economic damage, air pollution, oil field, Kazakhstan

INTRODUCTION

Today, secondary to continuous industrialization of the society the anthropogenic environmental impact has increased manifold, which cannot help affecting the health of the exposed population. According toWHO reports, globally only 3.7 million deaths were attributable to ambient air pollution in 2012. About 88% of these deaths occured in low and middle income countries [1]. Former Soviet republics, including the Republic of Kazakhstan (RoK, Central Asia), just can be attributed to those middle-income countries, where the health care services desperately need to harmonize the existing post-Soviet legal documentation with the international practices. In this connection, the main goal is to identify the main risk factors for occurrence of additional morbidity and mortality in various environmentally disadvantaged areas, including oil and gas facilities, like the Karachaganak field (KOGCF) discovered in 1979 on the territory of the western Kazakhstan.

Being one of the largest oil and gas condensate fields in the world it has an estimated 1.2 billion tons of oil reserves. In view of continuous emissions of combustion products from the field, for more than 20 years the air quality and human health have been continuously monitored in the nearest villages (5-15 km) with a total population of 9,000 people. Moreover the health status of the exposed population was compared with that of Alexandrovka village which is similar to the exposed villages according to the climate, geographic position, socio-economic, gender and age parameters but is situated at a significant distance (50 km) from the field [2-4].

The sociological survey made by Alikeeva in 2009 in the nearest village Berezovka (5 km from the field) showed that over 90% of respondents have mentioned a specific odor in the air: oil products (12%), ammonia (12%), and especially rotten eggs (73%) [5]. As explained by Hirsch et al., rotten eggs odor is typical for hydrogen sulfide (H_2S). Inhalation of air containing a small amount of hydrogen sulfide causes dizziness, headache, and nausea whereas significant concentrations lead to coma, convulsions, pulmonary edema and even death [6].

In 2006 Erzhanova with the use of a multiple regression analysis between morbidity and concentrations of chemical elements in the air of Berezovka village confirmed the influence of hydrogen sulfide chronic exposure on appearance of additional cardiovascular morbidity cases [7].

Human health risk assessment from the KOGCF emission, based on modeled data (Kenessariyev et al. in 2011) did not include hydrogen sulfide into the air pollutants priority list due to insufficient share (less than 1%) from total emissions and low expected chronic concentrations of chemical that led to insignificant health risk (HQ<1) [8]. However due to numerous complaints from the habitants of the nearby villages a decision was made to include hydrogen sulfide into the list of chemicals to be constantly monitored.

MATERIALS AND METHODS

The data on H_2S was collected using the environmental monitoring stations (EMS) installed in the above mentioned villages.

Brief description of the EMS

Continuous monitoring of ambient air was done with the help of 14 EMS that automatically collected data for every 10 seconds. The data from EMS may be averaged for any length interval. The minimum detection limit is less than 0.00056 mg/m^3. The stations are connected to the emergency response services thus permitting timely alert of the local governments (akimats) and population when excessively high concentrations of pollutants, hazardous for health and life of population, are detected [9].

Determination of additional cardiovascular morbidity

According to Erzhanova A. [7] an increase in the daily average concentration of H_2S by 0.001 mg/m^3 increases by 1.1 times the cardiovascular morbidity (if by 0.002 mg/m^3, then 2.2 times, respectively). In this case 2 times increase means that 50% of general morbidity (*M*) is an additional morbidity due to increased concentration of H_2S (*Ma*). Therefore additional morbidity in percentage (*Ma%)* is a multiplication of quantity of times of increase (*k*) by 50% and divided by 2 times. So, additional cardiovascular incidence (*Ma*) was calculated with the next formula:

$$Ma = M * Ma\% / 100\%$$
$$Ma\% = k * 50\% / 2$$

Economic damage evaluation

Economic damage from morbidity is a sum of multiplication of a single case morbidity cost (Mc_y) and additional morbidity risk (Mr_y) calculated separately for each age group (*y)* – children, adolescents, adults, and seniors.

$$EDm = \sum Mc_y * Mr_y$$

Single case morbidity cost is a sum of a cost of a treated case (*TC*), sick-pay (*SIC*), disability benefits (*SSC*) and loss of tax revenue to the budget and extra-budgetary funds (*TRL*):

$$Mc_y = TC + SIC + SSC + TRL$$

Treated case cost is equal to the medical-economic tariffs, officially approved by the state in 2011 [10].

Sick pay cost was calculated by multiplying the cost of one day of disability according to the sick list (s), number of lost days of work (d) and coefficient of employed people share in the study group (k_w).

Disability benefits cost was not calculated due to the lack of data on disability from the explored diseases.

Loss of tax revenue to the budget due to sickness was calculated by multiplying *d* to k_w and average value of the total income tax attributable to spent man-day (t). This t-value consists of corporate income tax revenues (t_{ci}), personal income tax revenues (t_{pi}) and single social tax revenues (t_{ss}) and is calculated in a next way:

$$t = (t_{ci} + t_{pi} + t_{ss})/(d_w * Q_w)$$

where d_w — quantity of working days in a year; Q_w — quantity of working people in Kazakhstan for 2012.

RESULTS

Maximum average monthly concentrations of hydrogen sulfide in some of the selected villages exceeded the reference point concentrations in the range of 0.001–0.002 mg/m^3, as shown in Table 1.

Therefore it became necessary to quantify the degree of negative health impact from excess H_2S. Calculated additional cardiovascular morbidity cases caused by the increase in the maximum monthly average concentrations of H_2S equaled 67.1 cases out of total 166, including 57.2 additional cases of diseases among the working population (out of 141), 8.8 cases among seniors (out of 23) and 1.1 cases among adolescents and children (out of 2). The results of the calculations are shown in Table 2.

Economic damage from additional cases of cardiovascular diseases due to excess concentrations of H_2S equaled $59,610 and was highest among the Kiziltal habitants — $37,613 (Table 3).

Although the economic damage evaluation methodology used in this study might have similarities all around the world, the peculiarities of Kazakhstani health care system, taken into consideration while designing this exact specific method, have a number of differences. In particular, we used medical and economic tariffs (MET) [11] to calculate the cost of treatment instead counting the price of one day of hospitalization multiplied by the length of staying as

Table 1. *H2S monthly average highest concentrations in selected villages*

Selected rural ambulance (outpatient clinic)(RA), named by the location	Maximum monthly average concentration in 2012, mg/m³	Over the reference point village concentration, mg/m³
Berezovka (EMS 13-14)	0.002	0.001
Priuralny (EMS 8)	0.002	0.001
Zharsuat (EMS 7) (including Zhanatalap)	0.002	0.001
Kiziltal (EMS 10-11)	0.003	0.002
Alexandrovka RA (reference point)	0.001	

Table 2. *Additional cardiovascular morbidity*

Selected Rural ambulance		Berezovka	Priuralny	Zharsuat (including Zhanatalap)	Kiziltal
H2S concentrations (C), mg/m³		0.001	0.001	0.001	0.002
Dose-response dependence (k), times		1.1	1.1	1.1	2.2
Percentage of Ma out of M (Ma%), %		27.5	27.5	27.5	55
General morbidity (M), cases	Total	45	16	27	78
	adults	41	12	21	67
	seniors	4	4	6	9
	adolescents	0	0	0	1
	children	0	0	0	1
Additional morbidity (Ma), cases	Total	12.4	4.4	7.4	42.9
	adults	11.3	3.4	5.9	36.7
	seniors	1.1	1	1.5	5.1
	adolescents	0	0	0	0.55
	children	0	0	0	0.55

Table 3. *Economic damage from additional cases of circulatory system disease due to excess concentrations of H_2S*

Selected rural ambulance	Berezovka			
Age groups	1	2	3	4
Quantity of inhabitants, Q	1923	1359	132	52
Morbidity risk, Mry	12	11	1	0
Economic damage, EDm	11279	10679	599	0
Single case morbidity cost , Mcy	n/c	947	547	547
Cost of a treated case , TC	n/c	547	547	547
Medical-economic tariff	n/c	547	547	547
Sic-pay cost , SIC	733	367	n/c	n/c
Cost of one day of disability , s=ЗП/dw	n/c	53	n/c	n/c
Number of lost days of work, d	n/c	10	n/c	n/c
Coefficient of employed people share , kw	n/c	0.7	n/c	n/c
Loss of tax revenue to the budget , TRL	66.05143	3.3E+01	n/c	n/c
Average value of the total income tax , t	9.480516	4.7E+00	n/c	n/c
Corporate income tax revenues, tci	n/c	6.94E+09	n/c	n/c
Personal income tax revenues, tpi	n/c	2.92E+09	n/c	n/c
Single social tax revenues, tss	n/c	2.27E+09	n/c	n/c
Quantity of working people in a studied group, qw	939	939	n/c	n/c
Quantity of working days in a year, dw	n/c	301	n/c	n/c
Quantity of working people in Kazakhstan , Qw	n/c	8.51E+06	n/c	n/c

Comments: 1 — total number of people, 2 — adults, 3 — seniors, 4 — adolescents, 5 — children; n/c — no need to be calculated. Total cost denominated in the national currency tenge (KZT) was converted into USD at the exchange rate set by of the National Bank of Kazakhstan: KZT150 / USD1. Source: references [9, 20–25]

made in the Russian Federation. These tariffs already include the cost of payment for the medical workers, social taxes, nutrition and drugs. The cost of MET in our exact case is the arithmetic mean of the arterial hypertension and coronary heart disease MET, since in more than 90% of cases the above were diagnosed upon first visits of the Burlin district patients with cardiovascular diseases.

DISCUSSION

Although the negative impact of acute H_2S exposure is already known for decades, epidemiological data concerning longer-term exposures are still limited. Before the 1990s the main regulatory assumption was that if an exposure to H_2S is not fatal, there are few, if any, lasting health effects. But this view became medically outdated due to numerous investigations.

According to the research by Kilburn et al. symptoms of chronic exposure to H_2S include pronounced deficits in balance and reaction time, dizziness, insomnia, and overpowering fatigue [12]. These investigators stated that H_2S poisons the brain, and the poisoning is irreversible.

Legator et al. [13] determined that over 86% of the population under chronic exposure to H_2S experienced central nervous system impairment similar to that described by Kilburn et al. vs. only 26% of a reference point population (20 miles away from the plant). Tarver et al. also stated that people living near an industrial plant demonstrated attention deficits and an inability to process information quickly [14].

Teams of researchers at separate institutions have discovered evidence that H_2S even damages DNA [15–18].

The occurrence of low-level concentrations of H_2S around certain industrial installations is a well

	Priuralni					Zharsuat					Kiziltal				
5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
380	1232	667	204	38	323	2001	1263	329	67	342	3768	2165	303	160	1140
0	4	3	1	0	0	7	6	2	0	0	43	37	5	1	1
0	3944	3381	564	0	0	6774	5934	840	0	0	37613	33994	2808	301	510
947	n/c	1003	547	547	1003	n/c	1007	547	547	1007	n/c	927	547	547	927
547	n/c	547	547	547	547	n/c	547	547	547	547	n/c	547	547	547	547
547	n/c	547	547	547	547	n/c	547	547	547	547	n/c	547	547	547	547
367	837	418	n/c	n/c	418	844	422	n/c	n/c	422	697	348	n/c	n/c	348
53	n/c	53	n/c	n/c	53	n/c	53	n/c	n/c	53	n/c	53	n/c	n/c	53
10	n/c	10	n/c	n/c	10	n/c	10	n/c	n/c	10	n/c	10	n/c	n/c	10
0.7	n/c	0.8	n/c	n/c	0.8	n/c	0.8	n/c	n/c	0.8	n/c	0.7	n/c	n/c	0.7
3.3E+01	7.5E+01	3.8E+01	n/c	n/c	3.8E+01	7.6E+01	3.8E+01	n/c	n/c	3.8E+01	6.3E+01	3.1E+01	n/c	n/c	3.1E+01
4.7E+00	9.5E+00	4.7E+00	n/c	n/c	4.7E+00	n/c	4.7E+00	n/c	n/c	4.7E+00	n/c	4.7E+00	n/c	n/c	4.7E+00
n/c	n/c	6.94E+09	n/c	n/c	n/c	n/c	6.94E+09	n/c	n/c	n/c	n/c	6.94E+09	n/c	n/c	n/c
n/c	n/c	2.92E+09	n/c	n/c	n/c	n/c	2.92E+09	n/c	n/c	n/c	n/c	2.92E+09	n/c	n/c	n/c
n/c	n/c	2.27E+09	n/c	n/c	n/c	n/c	2.27E+09	n/c	n/c	n/c	n/c	2.27E+09	n/c	n/c	n/c
n/c	526	526	n/c	n/c	n/c	1005	1005	n/c	n/c	n/c	1422	1422	n/c	n/c	n/c
301	n/c	301	n/c	n/c	301	n/c	301	n/c	n/c	301	n/c	301	n/c	n/c	301
n/c	n/c	8.51E+06	n/c	n/c	n/c	n/c	8.51E+06	n/c	n/c	n/c	n/c	8.51E+06	n/c	n/c	n/c

known fact. Low-level concentrations may occur continuously in certain industries, such as in viscose rayon and pulp production, in geothermal energy installations and at oil refineries, where there is a high risk of exposure for the general population. A large accidental release of H2S into the air surrounding industrial facilities can cause very severe effects, as at Poza Rica, Mexico, where 320 people were hospitalized and 22 died [19].

As seen from the research on the impact of chronic H_2S exposure has been underestimated for a long period of time. People in countries with weak environmental protection regulations are constantly under chronic exposure to numerous chemicals, including H_2S that is an important chemical for Kazakhstan, since oil mining is one of the driving forces in the country's economy.

CONCLUSION

Hydrogen sulfide air pollution due to the KOGCF activity costs Kazakhstan budget almost $60,000 per year. Moreover, this is the reason for over 40% rise of cardiovascular morbidity in the affected villages. In this regard the reduction of hydrogen sulfide emissions into the air is recommended, as well as successive constant ambient air monitoring in future.

We suggest that evaluation of economic damage should be made mandatory, on a legal basis, whenever an industrial facility operations result in associated air pollution.

The results of this research should be included as determining an expense item in the statutory payments made by an enterprise to the government, in order to rehabilitate the health of the exposed population, within the framework of the Free Public Health Care system.

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