Study of the Influence of Winds in the Potential Contamination with Hazardous Substances as A Result of Man-Made Accidents

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Abstract. The report presents enterprises on the territory of Bulgaria that store or use in their production dangerous chemical, radiation and biological substances. An analysis was made of the substances used and the conditions for use and storage. In the event of an accident, these hazardous substances will pollute the environment. Wind plays a major role in dispersal of released substances and will determine the contaminated area. The direction and strength of winds at different altitudes in the settlements where these enterprises are located were studied. The obtained results were analysed based on the prevailing winds in the last 20 years.
Keywords: direction, distribution, hazardous substances, man-made accident, storage, wind.

I. INTRODUCTION

Bulgaria built a powerful chemical industry in the second half of the twentieth century. It had a wide range of productions using many chemicals and in large quantities. Geographically, these plants were located all over the territory of Bulgaria, being aligned with mineral deposits, ports, airports and transport corridors. On the territory of Bulgaria there are many factories with chemical production or those that use chemical substances [1], [2].

The chemical industry is high value added, has a high return on investment and is constantly evolving. The products of the chemical industry are used in all branches of the modern economy, and any production without these products is unthinkable [3]

At the same time, enterprises using large quantities of chemical substances are under continuous monitoring and control by state, governmental control bodies and environmental organizations [4], [5]. This is due to the fact that harmful or dangerous substances are very often released during these productions and they are not always disposed of or released in the correct non-polluting way [6].

II. MATERIALS AND METHODS

A. Main operating enterprises from the chemical industry in Bulgaria

a) Agropolychem

Agropolyhim is a leading producer of nitrogen fertilizers in South-Eastern Europe and a leader in the production of phosphorus fertilizers in the Balkan Peninsula. The plant is located in North-Eastern Bulgaria, about 30 km from the city of Varna.

The plant was put into operation in 1974 with the main goal of meeting the needs of Bulgarian agriculture. In 2009, a new plant for concentrating phosphoric acid up to 54% was completed, which made it possible to export phosphoric acid to the Balkans and central Europe. The value of this investment is 11 million euros.

Here it became possible to produce new products depending on the needs of the market - monoammonium phosphate (MAP), diammonium phosphate (DAP) in a volume of up to 1100 tons per day.

In 2011, Agropolychem realized the construction of a new workshop for the production of pure ammonium nitrate solution and the utilization of condensates with a capacity of 1250 t/day at its production site in the town of Devnya.

b) "Neochim" JSC

"Neochim" JSC is the successor of the Chemical Combine in the town of Dimitrovgrad, which started its production activities on November 5, 1951. Initially,

Print ISSN 1691-5402
Online ISSN 2256-070X
https://doi.org/10.17770/etr2024vol1.7988

nitrogen and phosphorus fertilizers were produced. Subsequently, expansions, reconstructions and modernizations of the production facilities were made. In 1987, a new complex for the production of ammonia, nitric acid and ammonium nitrate was commissioned.

In the period 1992-1993, the installations for the production of sulfuric and phosphoric acid, phosphoric fertilizers, aniline and nitrobenzene were shut down. The activity of "Neochim" AD is the production and trade of mineral fertilizers, inorganic and organic chemical products.

Structurally, production capacities are grouped into: nitrogen fertilizer complex and organic production. The operated installations for the main products allow to produce: ammonia 450,000 t/year; nitric acid 480,000 t/year; ammonium nitrate 710,000 t/year; sodium nitrate 9,300 t/year; formalin 30,000 t/year; urea-formaldehyde resins 20,800 t/year; Ammonium bicarbonate 6,000 t/year.

"Neochim" AD is the only producer in Bulgaria of formalin, urea-formaldehyde resins, sodium nitrate, ammonium bicarbonate, paradise gas, polyethylene oxide, glass-filled thermoplastics, etc. Agropolichim owns a warehouse for the storage of liquid ammonia with a capacity of 10,000 tons.

The most significant potentially dangerous object on the territory of Haskovo region is "Neokhim" JSC - Dimitrovgrad, categorized as an enterprise with high risk potential (permit No. 01-10/2012, issued by the Minister of Environment and Water). The main production facilities are currently producing: ammonium nitrate; ammonia; nitric acid; formalin and urea-formaldehyde resins; nitrogen and oxygen; carbon dioxide; nitrous oxide (paradise gas); sodium nitrate and sodium nitrite. The company operates and stores: ammonia (by cryogenic method) - up to 10,000 tons; nitric acid - up to 6500 t; formalin - up to 2200 tons; liquefied hydrocarbon gases (propane-butane) - up to 113 t; natural gas – by pipeline; sulfur dioxide (liquefied) - up to 100 tons; ammonia (25% aqueous solution) - 100 tons; ammonium nitrate - up to 10,000 tons. Ammonia is an explosive and highly toxic gas, and in the event of an accident, a zone of lethal concentration will be formed in an area of 7.5 km^2, including 7 settlements, with a total number of affected population of 58,000 inhabitants and a zone of striking concentration in an area of 40 km^2, including 17 settlements and about 15,000 inhabitants.

c) Air Liquide Bulgaria

Air Liquide Bulgaria signs a long-term contract for the supply of oxygen and argon to Steel Industry in Pernik and uses this opportunity to invest in a new plant supplying Steel and also producing large quantities of liquid oxygen, nitrogen and argon. They have two air separation plants in Pernik and Pirdop, which supply large quantities of oxygen to the Aurubis Bulgaria and Stomana Industry plants.

For the needs of the Bulgarian industry, apart from oxygen, argon and nitrogen are also produced there. There are filling centers for bottles in Gabrovo and Pirdop. Distribution centers are open in Sofia, Varna, Gabrovo, Ruse and Dobrich.

d) "Plasthim-T" Bulgaria

"Plasthim-T" is among the main producers of flexible packaging in Bulgaria. The enterprise has existed since 1967, mainly as a manufacturer of household and electrical appliances. From the end of the 70s, the production of polypropylene twine began, and from that time, the production of polyethylene film. Since 1983, the production of flexible packaging has started. In 1990, the production of flexible containers began. They have a line for the production of biaxially oriented polypropylene (BOPP), which was successfully launched in 2004.

In March 2010, a production line for BOPP foil with a width of 6.6 meters was launched. The company's production also uses the metallization process. It consists in the vaporization of a metal at very low pressure, which causes a deposit on the substrate, which is actually an adhesion of the metal, giving it certain technical characteristics or improving its appearance.

e) Tecom Company

The company "Tecom" was established in 1984 with the subject of construction chemistry in the utilization of industrial waste for composite materials and technologies. The company builds modern technological lines for the production of concrete additives, formwork oils, flocculants, auxiliary products based on organic chemical synthesis and nanotechnology.

In 2002, the company acquired the "Tecom" factory - the village of Gorna Malina, where it built a technological line for the production of polymer and silicone primers, silicone impregnators and hydrophobizers for protection against aggressors, polymer and silicone plasters, dry construction adhesives, floor coverings, systems for sanitation, waterproofing products, etc. based on nanotechnology.

The company specializes in the production of the following groups of products: additives for cement concrete and solutions; ancillary products; formwork oils; polymer and silicone primers; silicone impregnants and hydrophobizers; polymer and silicone plasters; dry construction adhesives; floor coverings; sanitation system; waterproofing products; flocculants.

Since 2010, Tecom has included in its production list the Carboplast series of superplasticizers based on polycarboxylate ethers.

B. Major industrial toxicants

a) General information about industrial toxic substances

Modern technical progress is unthinkable without the intensive development of chemical science. In the various productions, a large part of the substances obtained (intermediate or final) are toxic. Their storage is carried out in warehouses (drums, bottles or tanks), installations and technological lines. They are equally dangerous for personnel and the population both in peacetime and in wartime. Contamination with them can be large in area and, depending on the physico-chemical properties, persistent for minutes, hours and days [2], [7].

Regardless of strict safety measures, emergency situations accompanied by the release into the atmosphere of poisonous vapors (aerosols) or liquid spills are not a rare phenomenon.

For example, in the Indian city of Bhopal, 43 tons of methyl isocyanate and other industrial poisons leaked due to an accident at the plant of the American corporation "Union Carbide", as a result of which 3,150 people died, and more than 200,000 remained crippled for life [1], [8].

A large chlorine leak in one of the city's chemical plants is threatening the lives and health of people in Toulouse, France.

At the beginning of 2017, in the village of Hitrino, a tanker truck crashed with a subsequent explosion. It's basically a volumetric explosion of propane and acrolein. Over a hundred houses were destroyed and dozens died. For more than 10 days, the security of the tankers, carriers of various industrial substances, continues [2], [9].

That is why it is advisable to know the striking effect of industrial poisons, the ways of using the means of personal protection and the abilities of self-help and mutual aid.

Commanders and staffs are required to have a competent assessment of the complex chemical situation that has arisen and the ability to creatively organize measures to protect against industrial accidents [10].

What should we understand by industrial toxic substances (POS). They include not all harmful components of the industry, but only those that are capable of contaminating the air in dangerous concentrations and thereby causing mass destruction of varying degrees of severity.

The main industrial poisons are chlorine, hydrogen chloride, ammonia, sulfur dioxide, sulfur trioxide, phosphorus halides, hydrogen fluoride, carbon monoxide, methyl mercaptan, benzene, dichloroethane, etc.

These chemicals are obtained and used by our chemical plants and factories.

Based on the fact that in the event of an accident in peacetime (including an accident as a result of a terrorist act) and in the case of deliberate use in wartime, industrial poisons will have a significant impact on the chemical situation in the nearby areas of chemical plants (and in the case of an inversion - on a large part of the country's territory), it is necessary to know the basic properties of the troops that will operate in these areas when providing assistance to the population or when conducting combat operations [2], [11].

Table 1 gives the concentrations of some thought poisons that affect the skin and poisons that cause death at the corresponding exposure (residence time in the contaminated atmosphere or workplace).

TABLE 1. CONCENTRATIONS OF SOME INDUSTRIAL POISONS

№	Industrial poisons	Toxic properties			
		skin damage, mg/l	exposition	lethal concentration, mg/l	exposure in minutes
1.	ammonia	0,2	6h	7	30
2.	chlorine	0,01	1h	0,1– 0,2	60
3.	carbon monoxide	0,22	2,5h	3,4– 5,7	30
4.	carbon disulfide	1,5– 1,6	1,5h	10	90
5.	phosphorus trichloride	0,08– 0,15	30 min	1,05	30
6.	hydrogen fluoride	0,4	1,5h	1,5	5

Industrial poisonous substances can be divided into four types according to toxicity, depending on the maximum permissible concentration (MPC). This is the maximum amount of substance in a unit volume of air, which does not lead to damage to the body during prolonged exposure:

- extremely dangerous - MPC less than 0.1 mg/m^3;
- highly dangerous - MPC 0.1-1.0 mg/m^3;
- moderately dangerous – MPC 1.0–10 mg/m^3;
- slightly dangerous – MAC more than 10 mg/m^3;

When the highly effective poisonous substances are poured or leaked, the so-called chemical contamination zone (3X3). It includes the place of the accident (destruction) - the so-called focus of defeat, and the territory within which the contaminated air (CA) spreads with striking concentrations. This area can reach hundreds of hectares.

The seriousness of the problem of the spread of industrial poisons can be seen from the following example. In the event of an accident (release) into the atmosphere of 10 tons of chlorine ($C1_2$), the dimensions of the cloud with lethal concentrations will be 4.8 km long and 1 km wide, and with striking concentrations - 22 km and 4 km, respectively. When 100 tons of chlorine are released into the atmosphere, the dimensions of the deadly cloud are: length 22.1 km and width 4.4 km, and the cloud with striking concentrations - 100 km and 20 km, respectively. From the example, it can be seen that depending on the direction of the surface wind, large areas will be infected. The depth of spread of contaminated air (CA) depends, first of all, on weather conditions. So, for example, with increasing temperature, rapid evaporation of IOB occurs, the concentration in the air increases, and hence the areas of damage. A strong wind, on the other hand, leads to rapid dispersion of the cloud with dangerous concentrations [12], [13].

b) Classification of air pollution accidents.

Accidents in the chemical industry with air pollution, depending on their degrees of contamination, are local, local and major (severe) accidents.

- Local air pollution accidents.

These are accidents that affect only a separate part of the production and contaminate the air to a limited extent

with POW. These accidents are accompanied by leakage of small amounts of POW from the gas communications /pipelines, apparatus, vessels/, which can be easily removed. With them, only individuals can be affected and the plant does not need to stop production.

- Local air pollution accidents.

These are accidents in which a large amount of POW leaks and a high degree of contamination occurs, which spreads throughout the workshops, but there is no danger of contamination outside the site. Production is partially or temporarily suspended.

- Major /severe/ production accidents with air contamination.

These production accidents lead to sudden stoppage of production, loss of material values and injury to people, as well as contamination of the air not only in the factory but also outside.

These accidents are often accompanied by explosions, fires and the dispersal of large amounts of POPs.

Large foci of chemical contamination are created, resulting in the formation of toxic clouds kilometers away, which are dangerous because they cause mass damage to people, farm animals and plants [5], [14].

Major industrial accidents can be divided into two groups:

- Major production accidents that cause contamination of the air with POW in large areas;
- Major production accidents accompanied by explosions, fires, destruction and contamination of large areas.

The second group of KPA are the most dangerous. With them, in addition to massive human casualties, material values are also destroyed, and in individual cases, entire factories.

This type of KPA will be the most common, given that the majority of POPs form explosive mixtures with air.

Chemical production enterprises, depending on the amount of produced, used or stored POPs and their toxicity (I, II, III or IV degree), can be graded according to their emergency danger in three categories (I, II and III category). Major production accidents with air pollution will also be a frequent occurrence in wartime, when the chemical industry will be exposed to enemy strikes and sabotage. The most common Industrial poisonous substances in the production sector are: ammonia, chlorine, sulfuric acid, caustic soda, sulfur oxides, blast furnace and coke gas, propane-butane, cyanides, pesticides and other substances.

TABLE 2. GRADING OF ENTERPRISES PRODUCING CHLORINE AND AMMONIA ACCORDING TO EMERGENCY RISK.

Category	**chlorine /t/**	**Ammonia /t/**
First category of emergency safety	Production over 200	Over 2,500
Second category of emergency safety	Production from 50 to 200	From 500 to 2,500
Third category of emergency safety	Production from 1 to 50	From 20 to 500

IV. RESULTS AND DISCUSSION

Meteorological elements can have an impact on the pollution of our surrounding environment - atmosphere, soil and water, and each indicator has a different weight in forming the degree of pollution with toxic or industrial poisonous substances. Naturally, the winds at different heights from the surface of the earth's crust have the strongest influence on the spread of gases from a chemical accident, accident or terrorism. In the different layers of the Earth's atmosphere, the direction and speed of air currents sometimes have radically different values. Different types of horizontal and vertical precipitation and the permeability of the atmospheric layer to the solar radiation reaching us also have an influence. The other meteorological components have a negligible influence on the distribution of radioactive rays, particles and isotopes and are therefore not the subject of this report [2], [15].

Several of Bulgaria's large chemical enterprises are located in the considered region of Central Northern Bulgaria. There are also chemical industry enterprises here on both sides of the border river Danube and former enterprises that are currently not working, but have worked and have raw materials or can work again. All of them can have an impact on people and our surroundings in the event of an accident. There are also many medium and small enterprises that work with hazardous substances and we should not ignore their influence in the event of a release of hazardous or toxic substances.

An analysis of the results of the movement of air masses in the last nearly 40 years has been made, and relevant conclusions and recommendations have been made based on them.

Influence of winds

Wind and air currents have the greatest influence on the change in our environment after an accident occurs in facilities where there are large amounts of chemical substances. The direction and speed of the average wind determine the location, scale and degree of contamination of the trail of released gases. Therefore, when assessing possible pollution, the parameters of the air currents must always be taken into account. In the event of an accident or an increase in the concentration of chemical substances or gases, we must constantly monitor the change in air currents, as well as inform ourselves about the possible changes that meteorologists give in their forecasts. It is also necessary to quickly collect information about the usual winds in the given area, in order to predict the direction of the spread of gassing, using also local signs to determine the winds and their future development. In Bulgaria, you can use the National System for Continuous Environmental Control at the Ministry of Environment and Water and the website of the National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences, where you can see what the distributed chemical substances will be after a certain set time and at a certain height on the earth's surface for a specific enterprise [1], [3], [16].

Wind direction and speed data allow us to solve the following tasks:

1. Determining the direction of spread of gassing and the scale of pollution, as we can define it for a certain time segment;

2. Determination of the arrival time of the chemical pollution to the designated area under the current and predicted air currents;

3. Determining the level of the assumed change in the concentration of gases in a certain time range.

The most dangerous enterprise in Central Northern Bulgaria is the chemical plant "Sviloza" in the city of Svishtov, where synthetic fibers are produced and there is a large content of heterogeneous chemical substances.

The analysis was made on the basis of detailed statistical data on the direction and strength of the wind and air currents over the territory of Bulgaria in the last more than 40 years after 1992 from the database of the National Institute of Meteorology and Hydrology (NIMH) at the Bulgarian Academy of Sciences (BAS).

In addition to the daily data for the period after 1992, generalized values for the direction and strength of the winds were used, both near the border areas with neighboring countries and over the territory of our entire country. Here, data for a period of 30 years is used, which is quite sufficient to capture the trends in the change of the atmospheric masses and the adjacent water and land surfaces. I must point out that the tracking of air masses for the last 30 years only gives us the trends and the main directions of movement, but as we all know these processes are too dynamic and do not obey cyclical uniform repeatability and predictability. Therefore, at the same time as the in-depth research and data processing, we must not stop the constant monitoring of our environment and its parameters [17], [18], [19].

Of particular interest to us are the changes in the direction of the movement of air currents in the border regions, near which there are nuclear facilities, and this applies most strongly to the cities along the Danube River. This is explained by the fact of the location of the largest chemical enterprise in the region - "Sviloza" in the town of Svishtov. Further down the river, about 100 kilometers away, is the city of Ruse, where since the 1980s significant gas emissions have been observed, both from the Bulgarian and Romanian sides. Along the Danube River is also the battery plant in the city of Nikopol (which has been capacity-constrained in recent decades) and the Kozloduy NPP in Bulgaria, the Cherna Voda NPP in Romania and the site of the frozen Belene NPP in Bulgaria [1], [20], [21].

TABLE 3. WIND FREQUENCY IN 8 DIRECTIONS AND AVERAGE SPEED IN THE CORRESPONDING DIRECTION FOR THE PERIOD 1992 - 2024 FOR THE AREA OF THE TOWN OF SVISHTOV.

Direction	N	NE	E	SE	S	SW	W	NW	Quietly
Number of cases with quiet, %	6.2	14.1	7.1	3.8	5.9	8.2	15.6	7.6	31.5
Number of cases without quiet, %	9.0	20.7	10.3	5.6	8.6	11.9	22.8	11.1	
Average speed, (m/s)	4.7	4.4	2.6	2.9	3.6	3.4	3.8	3.0	

Table 3 shows that the main wind direction in this region is west and northeast. To the west of Svishtov is located "Svilosa" Svishtov and the construction site of the NPP "Belene" and it is from there that 22.8% of the winds originate. Adding the nearby northwesterly and southwesterly winds, it turns out that more than 40% of the winds in this area would contribute to an increase in pollution in the event of an accident at the nearby enterprise within the city limits. Here, the wind speed must be taken into account when assessing the situation. Table 3 clearly shows that the west wind has a high speed - more than 3.8 m/s, with a higher speed only the pure north wind - 4.7 m/s and the northeast wind - 4.4 m/s.

TABLE 4. WIND FREQUENCY IN 8 DIRECTIONS AND AVERAGE SPEED IN THE CORRESPONDING DIRECTION FOR 2023 FOR THE AREA OF THE TOWN OF SVISHTOV.

Direction	**N**	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**	**Quietly**
Number cases wi quiet, %	9.1	20.7	9.0	2.9	4.6	7.0	11.5	5.3	29.9
Number cases without quiet, %	13.0	29.6	12.9	4.2	6.4	10.0	16.4	7.5	
Average speed, (m/s)	4.3	3.6	2.4	2.5	2.3	2.6	3.2	3.1	

Table 4 shows the similar study, but taken only for the year 2023. Here, the trend with the prevailing direction of the winds is even more clearly defined - almost 30% of the days with wind were westerly, north-westerly and south-westerly. This shows us how necessary the functioning of environmental monitoring and weather forecasting systems is mainly with preventive activities [4], [20], [22], [23].

The wind roses in other border areas of Bulgaria, which are located next to potential sources of chemical enterprises, are of interest, but due to the limited volume of the report, I will present them in detail in another development. Similar are the results obtained in Ruse, Silistra, Kozloduy and Vidin, which are located along the Danube River and are respectively located east, next to and west of the Kozloduy NPP. Predominantly, the winds are westerly and are along the Danube River, with 33% being purely westerly and another 12-16% northwesterly.

IV. CONCLUSIONS

1. Air currents have the greatest influence of meteorological elements on the distribution of hazardous chemical substances in the air and the surface soil layer. Knowledge of the gases that are released in a chemical spill or chemical accident at a manufacturing facility is paramount in early action. The availability of data for previous years allows us to make predictions about possible impact and take preventive measures to limit the impact.

2. The topography of the area also has a significant influence on the spread of hazardous chemicals and released gases. A good knowledge of the surrounding environment significantly increases the possibilities of adequate behavior and limiting the impact in the event of an accident or emergency.

3. Air currents are a very dynamic process both in time and at different heights above the earth's surface. This change must be continuously monitored in order to be able to react quickly and adequately in the event of a chemical emergency. It is desirable to use forecasts of air transformations at different heights above the earth's surface.

4. Knowledge of the enterprises and warehouses where chemical substances and gases are stored or used is essential when managing an incident, accident or emergency situation. Strict control over the transportation of dangerous goods and compliance with the relevant documentation is also necessary.

ACKNOWLEDGMENTS:

This report is supported by the National Scientific Program "Security and Defense", approved by Decision No. 171/21.10.2021 of the Council of Ministers of the Republic of Bulgaria.

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