Measures to improve environmental safety of urban gas stations

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Abstract. Placement of gas stations (gas stations) in the city, as a rule, is not ordered. In connection with the current development of the city, the placement of the gas station is a point building on the free places, which leads to a violation of the norms and deterioration of the environmental condition in the territory of the nearest building. The authors systematize the factors affecting the environmental safety of gas stations in the urban area. This was done on the basis of previously obtained results of theoretical and experimental studies, as well as the results of numerical simulation. It became possible to characterize the degree of influence of existing or newly built gas stations on the environment. The algorithm of complex assessment of ecological safety of gas stations is offered on the basis of system of the revealed factors. Practical recommendations were developed to reduce the negative impact of existing and newly designed gas stations on the nearest development.

1. Introduction

In recent years, there has been a steady upward tendency to increase the number of motor vehicles in Russia. As a result, the need for liquid fuel oil increases and it is required to gas stations construction both outside and directly within a city.

Even use of modern technologies of petroleum products storing and strict construction and operation rules gas stations are still objects of increased danger. In addition, they are fire dangerous, explosive objects and they are sources of harmful substances constant release into the environment (figure 1) [1].

Gas stations within a city are usually located close to industrial, public, residential buildings and represent infill construction at vacant places [2].

Requirements documents regulate different distances of roadside clear zone from a gas station to residential buildings. With relation to fire and explosion hazard the distance shall be at least 25 m. According to SanPiN 2.2.1 / 2.1.1.1200-03 «Protected sanitary zones and sanitary classification of enterprises, structures and other objects», gas stations for refueling trucks and cars with liquid fuel belong to Class IV hazard and are regulated by at least 100 meters distance from residential buildings. Construction norms on urban planning previously determined a distance at least 50 m. The updated version of the SNiP for Urban planning doesn’t standardize the value, but refers to the documents indicated above. The situation with contradictory normative technical documents requirements doesn’t...
provide adequate environmental protection and requires additional protective measures development [3,4].

Figure 1. Gas stations influence on the environment within a city.

2. Research problem statement
The authors set the problem of developing practical recommendations for gas stations environmental safety improvement and its negative impact on the environment reduction. Theoretical studies [5-9] on the assessment of pollution of the atmosphere surface layer with harmful substances during construction and operation of a gas station were carried out. Authors found that one of the determining climatic factors of surface layer pollution is aerodynamics of wind flows from a gas station to the adjacent residential area. The authors conducted experimental studies in the aerodynamic chamber [10] and numerical simulation of air-gas flows dispersion from a gas station in ANSYS program [11].

The experiment in aerodynamic chamber and numerical computer simulation confirmed our assumption that gas station location from residential buildings at the distances recommended in isn’t conducive to human living near gas station safety due to exceeding the maximum permissible concentrations of harmful substances. The area of MPC excess of gasoline vapors at a residential nine-story building located 50 m far from a source of pollution is shown in figure 2. Harmful substances distribution comes from underground tank breather tube during filling. The air flow is directed towards the residential building.

It is obvious that directly in front of a residential building there is MPC excess (at some areas in dozens of times).

3. Research methodology
Decomposition of influence factors on the environmental situation in a city is based on studies results conducted by the authors, in order to develop practical recommendations for impact of gas stations reducing. The hierarchical approach was used to analyze and systematize the whole variety of factors influencing the possibility of forming an adverse environmental situation and determining gas stations environmental safety. Decomposition of harmful factors according to the hierarchy allowed to detail and specify all factors in order to ensure gas stations environmental safety in urban areas (figure 3).
Figure 2. Gasoline vapors distribution.
Boundary conditions: air flow velocity-3.3 m/s; concentration of gasoline vapor emission of 480 g/m³ and a speed of 1.33 m/s.

Figure 3. Factors affecting the environmental safety of gas stations within the city.

All factors were divided into six main categories: natural and climatic (NC), urban planning (UP), architectural and planning (AP), technological (TI), technical (Tn), qualitative (Q) [12-17].

Natural and climatic factors (NC) include meteorological conditions such as wind speed and direction, fog, calm, precipitation, and terrain. The way of harmful substances distribution from a gas station largely depends on the prevailing wind and its speed. Harmful substances distribution is considered under adverse weather conditions (fog and rain). Fog lying over wet gas station surface helps to clean the air from harmful substances. Level of surrounding area pollution also depends on terrain, uneven terrain affects air flows movement and turbulence that leads to harmful substances uneven dispersion.

Urban planning factors (UP) take into account buildings location relatively to gas stations and roadside clear zones between them, buildings around a gas station that help contain explosives spread:
trees, shrubs, household buildings, screens and fences. Any obstacles between gas stations and nearby buildings cause air flow changes and creation of additional vortex areas that affect explosives concentration.

Architectural and planning factors (AP) take into account the plan and arrangement of objects on gas station territory (operator's, fuel-dispensed columns with a shed, breather tubes, additional household structures), and also take into account their shapes and sizes [18,19].

Technological factors (Tl) take into account technological features applied at a gas station: tank filling technology (using a loopback circuit), modern technological equipment use, car refueling procedure and qualification level of gas stations employees.

Technical factors (Tn) take into account technical condition and term of service of gas station equipment, tank farm composition (volume, quantity, location method: underground or aboveground), gas stations capacity that is directly related to the number of fuel dispensers. Cars passing through the territory of gas stations also make a significant contribution to ecological situation at gas stations and near the other buildings.

Qualitative factors (Q) take into account background concentration of explosives presence near gas stations as well as type and quality of fuel sold. Fuel quality has a significant impact on the concentration of released explosives.

Climatic, urban planning, architectural and planning factors affect explosives spread from gas stations and help to reduce pollutants concentration by changing air flow direction and structure. Technological, technical and qualitative factors do not affect the process of explosives distribution, but on initial amount of explosives released and contribute to large emissions prevention. Only all factors considered it’s possible to achieve gas stations environmental safety within a city [20,21].

The authors introduced a parameter - degree of influence (\(\varepsilon\)), characterizing contribution of a factor to explosives distribution from gas stations. For each factor a detailed gradation of influence on explosives distribution was developed (from 0 to 1). Where 0 is no effect and 1 is high influence.

The parameter allows to assess the influence of all factors and almost don’t expose (\(\psi\)) the existing or newly built gas station in a city without complex mathematical calculations and numerical simulation. Gas station hazard indicator is defined:

\[
\psi = \sum_{i} k_i \cdot \varepsilon_i
\]

where \(i\) - factors affecting harmful substances distribution from gas stations; \(\varepsilon_i\) - degree of a factor influence; \(k_i\) – part of a factor contribution.

Each factor makes a different contribution for improving gas stations environmental safety so a parameter of part of a factor contribution was introduced. The value was obtained due to experimental studies and numerical modeling and was fixed for each factor. The sum of all six parts is equal to one.

4. Research results

One of the main factors contributing to explosives diffusion reducing from gas stations is urban planning and architectural planning. Urban planning activities include additional obstacles creation between a gas station and nearby buildings in green spaces forms (bushes, trees). Close multi-row trees and bushes planting is an effective obstacle for explosives spreading from gas stations during operation, as well as for dust released during construction. Architectural and planning activities take into account gas station location and its plan, based on airflows around.

During experimental studies, it was found that an additional obstacle or a change in gas stations design contributes to a change in air flow structure and creation of additional vortex regions that affects the process of explosives dispersion.

Based on results of theoretical, experimental studies and numerical modeling, taking into account the algorithm of environmental safety assessing of proposed indicator of gas stations environmental hazard, we can conclude that it is necessary to introduce measures to lower the environmental hazard
index and improve the gas stations environmental safety in cities. Recommendations for existing petrol stations in cities, depending on the indicator of environmental hazard are presented in the table 1.

| Indicator of environmental hazard (ψ) | Level of a gas station environmental safety | Recommended measures |
|--------------------------------------|---------------------------------------------|----------------------|
| 0.81 – 1                             | very low                                    | 1. Planting trees about 15 m height and planting width at least 25 m.  
2. Construction of non-residential buildings and structures.  
3. Protective screens installation.  
4. Artificial terrain change.  
5. Modern technological approaches introduction in gas stations operation.  
6. Replacing technical equipment with modern one.  
7. Tank farm reduction and thus gas station capacity. |
| 0.61 – 0.8                           | low                                         | 1. Planting trees about 15 m height and planting width at least 25 m.  
2. Construction of non-residential buildings and structures.  
3. Protective screens installation.  
4. Artificial terrain change. |
| 0.41 – 0.6                           | medium                                      | 1. Planting trees and bushes.  
2. Environmentally friendly engineering structures use, including biopositive greened noise-reducing screens.  
3. Modern technological approaches introduction in gas stations operation. |
| 0.21 – 0.4                           | high                                        | 1. Planting trees and bushes.  
2. Protective screens installation |
| 0 – 0.2                              | very high                                   | Measures aren’t recommended |

During gas stations construction, in addition to above recommendations for environmental safety improving (see the table), it is also necessary to take into account:

- wind direction and speed. It is necessary to locate gas stations in such a way that residential and public buildings are not in wind movement direction;
- take into account roadside clear zone between gas stations and residential (public) buildings not less than 100 m. Otherwise, arrange additional measures to reduce gas stations influence;
- develop a gas station plan in such a way that air flows through the territory of the gas station contribute to the dispersion of explosives released;
- during the construction of gas stations, it’s necessary to take into account vehicles flow and, if possible, not arrange a large number of fuel dispensers and not use large volume tanks.

5. Conclusion

The authors, based on the results of theoretical and experimental studies, as well as numerical modeling, determined the factors affecting the spread of harmful substances released at gas stations. A new approach was proposed taking into account all factors, to assess the environmental safety of existing and newly built gas stations within a city without complicated mathematical calculations and numerical modeling. On base of obtained indicator of gas stations environmental hazard, necessary measures have been developed. Practical recommendations were proposed to help to reduce the influence of gas stations in a city on nearby buildings and to improve environmental situation.
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