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Prospective application of Lidar Scanning during ambient air contamination control at offshore oil fields

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ABSTRACT

Organization and development conditions of ambient air contamination control stations available at onshore and offshore oil fields differ significantly. In the former case, when organizing production control at onshore facilities considering well-established practice, no special restrictions are recorded both for the development and location of a stationary network of the control stations, and for route and flare measurements. Organization of the control system at offshore facilities is determined by special conditions and requirements which is associated with a technical solution for deployment of the control stations in the aquatic area on the one hand and outfit of independent power supply utilities, and reliability of the systems and their self-sufficiency from the climatic conditions, on the other hand. Considering this, common process specifications applied to the ambient air contamination control systems do not possess a sufficient potential for their application at offshore facilities. A brief empiric assessment of various concepts for organization of production control of ambient air contamination at oil fields offshore facilities in the North Caspian Sea aquatic area considering their optimistic application and economic feasibility of their application is provided in the analytical review. The ambient air contamination control system including implementation of Lidar complexes for distant reconnaissance is a prevailing trend in the concepts assessed.

Key words: Lidar, Ambient air, Emissions of contaminants.

Article type: Research Article.

INTRODUCTION

Within the vital requirements of the environmental standards (Mityagina & Lavrova 2016), emission assessment in the course of the production environmental control (PEC) shall be based on the results of the instrumental measurements excluding computational methods, which requires implementation of innovation systems of ambient air contamination control and emissions of harmful substances at oil fields (Arekhi *et al.* 2020; Sawadogo-Ilboudo *et al*. 2021). The purpose of the provided empirical analysis is to identify an efficient concept of the ambient air contamination control system (AACC) for offshore facilities including:

Technical and economic assessment of implementation and realization of the concepts;

Technical provision of the above concepts with measuring analytical equipment developed based on the principles of express analysis of the contaminants' concentrations in ambient air and emissions;

Technical solution of online processing and data transmission on the level of ambient air contamination to the interested parties;

Metrological support of the concepts for relevance of the equipment to the requirements within technical regulation;

Assessment of production safety risks during implementation of the concepts.

The North Caspian Sea aquatic area is characterized by outstanding climatic conditions:

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Short-term surges and retreats of the sea level in the shallow water areas;
Drifting fast ice in winter;
Significant seasonal amplitudes of the temperature regime variations.

MATRIALS AND METHODS

According to the traditional practice, PEC is performed quarterly in the aquatic area of offshore oil fields (Pryde 1991) at conditionally stationary and flare monitoring stations using midget research vessels in warm season and snowmobiles (trucks) in winter. PEC prospective system within the monitoring of ambient air contamination and emissions of harmful substances from stationary sources shall be primarily determined by receiving online information to take timely decisions (Fang *et al*. 2014) aimed at prevention of a negative environmental impact and ensuring safe labor conditions of the personnel involved in operations at offshore oil fields, considering the following key regulatory technical conditions observed:
Maximum area coverage of the entire complex of offshore facilities considering the proportion of sanitary protection zone (SPZ). Measuring parameters of ambient air contamination and their transfer to the information processing center in continuous real time mode (Lazarescu 2013; Ibrahim *et al.* 2015). Provision of measurement tools with normative-technical and metrological regulations (Hunt *et al*. 2018) for representative express methods sensitivity during PEC performance. Elimination or minimization of restrictions during equipment operation based on operation-temperature regime and climatic conditions. Provision of the entire complex of ambient air contamination and emissions of harmful substances control system with reliable power supply. Minimization of demand in completeness with stand-by equipment and consumables. In the course of the prospective PEC system development, an important factor is the risk assessment by the criteria of production safety affecting both safety of oilfield facilities and personnel and quality of the works implemented within PEC (Fernández-Muñiz *et al*. 2019), in particular:
Application of mobile observation equipment. Explosion safety of the entire equipment package in case of emergency blowouts of explosive substances (hydrogen sulfide, methane and their derivatives).
Extreme weather conditions. The risks at operation of mobile observation tools include the following potential emergencies during:
Creation of interferences affecting helicopter flights safety;
Probable collision with offshore operations support vessels;
Probable collision of mobile observation equipment with stationary offshore structures and oilfield facilities.
The risks of explosion safety during accidental releases are as follows:
Short circuit or sparkage in power supply communications;
No or low level of spark extinguishing express analytical equipment protection;
Overheat and ignition of associated communication equipment.
The risks of extreme weather conditions affecting expedience and representativeness of measurements include:
Stormy wind ≥ 15 m s^{-1};
Intense rainfall ≥ 10 mm h^{-1};
Visibility at fog ≤ 2 scores (200 m);
Visibility at snowstorm ≤ 1 score (100 m);
Storm phenomena ≥ 3 scores.

RESULTS AND DISCUSSION

Based on the analytical assessment conditions, in addition to the common PEC system using midget vessels and snowmobiles, the following alternative concepts for organizing the supporting system for provision with and transmission of the online information on ambient air contamination status over the entire complex of the oilfield offshore facilities in discrete or continuous time mode were considered: Outfit stationary monitoring complexes at artificial islands (platforms) with modules of ambient air control and data transfer. Application of unmanned aerial vehicles (UAV) with modules used for ambient air control and data transfer. Involvement of stationary Lidar complexes for distant reconnaissance used for ambient air control and data transfer.

Organizing stationary survey network at artificial islands (platforms)

Control complexes located at the artificial islands (platforms) constructed with pre-installed modules of ambient

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air automatic control with discrete or continuous data transmission are considered as stationary monitoring network (Pryde 1991). An automatic measurement system SCAT including Radiocrafts PC 1280HP radio module transmitting the measurement results upon individual request or automatically was considered as basic-conditional specimen. The main technical requirements to AACC system arrangement stationary complexes are determined by: Installation of at least four AACC stationary complexes on SPZ perimeter including two stand-by packages of gas analytical equipment for rotation during its verification. Development of artificial islands or platforms with their deployment along the courses considering predominant wind direction, for installation of stationary complexes and independent power supply equipment. Provision of stationary observation complexes with automatic climate control systems. Provision of AACC stationary complexes with uninterruptible self-contained power supply. Installation of a PC complex at the oilfield for automatic receiving and processing of data from AACC stationary complexes and further data transfer to the interested parties.

Positive aspects of the system

1-No restrictions for gas-analyzing equipment in terms of operational-temperature mode and climatic conditions in the course of automated measurements.

2-Data transmission via radio channel in discrete mode or online mode.

3-Ability to install modules for the seawater quality control in stationary complex;

4-Automatic calibration of control module (gas analyzer). In this regard, no systematic calibration using verification gas mixtures is required.

5-Spark suppression system in ambient air and remote data transmission control module including associated equipment;

6-Acceptable cost of fit-out equipment and its maintenance;

7-No restrictions in access of specialists to the modular equipment both in stationary complex and to the independent power supply system.

Negative aspects of the system

1-Utilization of accumulator block for independent power supply to eliminate degradation of results due to overlapping of emissions from diesel-generator;

2-Equipment of the system of accumulator block automatic charge from diesel-generator in the precise time;

3-Switching-off ambient air control module in the precise time (depending on the season from 1 to 6 h/day) for charging accumulator from diesel-generator;

4-Additional sets of modular devices available for backup in case of failure or preventative maintenance of equipment and during rotation of gas analytical equipment during verification;

5-Risk of degradation of measurement results as a result of overlapping of emissions traces from engines of passing support vessels;

6-Necessity in regular preventative maintenance inspection of independent power supply system;

7-Probability of fire- and explosion hazard during operation of independent power supply system;

8-Significant development costs for additional artificial islands or platforms for deployment of stationary observation complexes.

Arrangement of monitoring stations and UAV application

Unmanned aerial vehicles with installed automatic AACC modules (Hardin & Jensen 2011; Siebert & Teizer 2014; Massabuau *et al.* 2015; Ebeid *et al.* 2018) and remote transmission of measurement results can be rated as mobile monitoring stations with their positioning at conditionally stationary control stations.

A DJI Agras MG-1 (Octocopter) drone completed with UAV tracking station Aaronia Drone Detection System - AARTOS DDS X9 and equipped with Polar- 2 Ex T gas analyzer with Radiocrafts PC 1280HP radio module transmitting measurement results is taken as the basic-conditional specimen.

The main technical requirements for organizing AACC system using UAV are determined by:

Six completed UAV available - five operating and 2 stand-by considering rotation of the verification procedures equipment;

Compliance of UAV technical specifications with the goals set:

- Free flight with actual load of at least 60 minutes;
- UAV controlled useful radius of at least 5 km;

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- Completeness with "cruise control" and "return to base" systems;
- Presence of positioning module (GPS) with ± 3 meters error;
- Completeness with gyro-module;
- Ability of UAV net load capacity at least 10 kg to install ambient air contamination control module completed with radio module used for transmission of measurement results;
- Ability to connect AACC module to the UAV remote control system;

Compactness of gas analyzing equipment for installation at UAV of max. 10 kg;
Available option of gas analyzing equipment to perform simultaneous measurements across the whole listing of the contaminants being determined;
Construction of PC complex at the oilfield used to automatically receive and process data from the modules installed at UAV with a station tracking safe UAV flight in the oilfield aquatic area and further data transfer to the interested parties;
Construction of a landing place for UAV at the oilfield and hangar space for parking.

Positive aspects of the system
Mobility potential of the system with ability of its application for wide range of studies including: ambient air contamination control, flare measurements and specialized measurements at additional stations;
Automatic calibration of gas analyzer (control module). In this regard, no systematic calibration using verification gas mixtures is required.
Measurement data transmission using stable radio-channel;
Completeness with spark suppression system for AACC modules and radio transmission;
Ability to program UAV flights based on the routes set with positioning (hovering) using "cruise control" mode in control points;
Ability to switch the control module automatically for measurements in control points through the UAV control system software;
Acceptable cost of complete set of equipment and UAV as well as their maintenance.

Negative aspects of the system
1-Impossibility to use UAV in continuous 24 h mode;
2-Data reception in discrete time mode only, which reduces prompt decisions to prevent, minimize or eliminate contaminants' emissions to the ambient air;
3-Insufficient sensitivity of AACC (gas analyzer) module if contaminants' concentrations are identified;
4-Dependence from the climatic conditions and restriction for operational temperature mode of the system equipment;
5-Limited period of UAV free flight, necessity to have a reserve of charged accumulators for the UAV;
6-Presence of additional UAV sets fully equipped with modular devices for backup in case of failure or preventative maintenance of UAV and modules, and for the period of gas analyzing equipment rotation during verification procedure;
7-Risk of measurement results' degradation as a result of overlapping emissions traces from engines of passing support vessels;
8-Necessity to allocate safe passage routes in the oilfield aquatic area in the course of measurements to eliminate emergency situations associated with collisions with vessels or helicopters;
9-Risk of UAV and installed equipment loss in case of probable collision with mobile vehicles or production facilities, and in case of strong wind;
10-Necessity to permanently track UAV location during measurements period.

Organization of monitoring using Lidar complexes for distant reconnaissance
An innovative system of remote control and forecast of air pollution on a real-time basis is based on application of Lidar complex (Hauchecorne *et al*. 1992; Pacheco *et al.* 2015; Bretschneider & Shetti 2015; Chuvieco 2016; Tulloch *et al.* 2019) composed of a laser module, information processing and remote online data transmission modules (El Hamzaoui *et al.* 2012). Biaxial (dual-frequency) monostatic Lidar ("Lasers and optical systems" CJSC) with remote control and data transmission was evaluated using basic-conditional specimen.

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The main technical requirements to organizing ambient air control system using Lidar complexes are determined by:
1-The arrangement of a computer complex for remote control of Lidar complexes in the oilfield, automated processing and transmission of data to the interested parties;
2-Construction of stationary towers at basic oilfield facilities to install Lidar complexes with a field of view ensuring direct visibility along the fixed beam sectors;
3-Ensuring measurement of pollutant concentrations using the method of spontaneous combining dispersion in routine mode and in case of emergencies;
4-Ensuring sufficient sensitivity of measurements of contaminants with a relative error of no more than 5% in the measurement range.

Positive aspects of the system
1-Sufficient number of Lidar sets to ensure full-scale range of the entire complex of offshore facilities by monitoring in the SPZ with a pickup radius from 0.1 km to 3 km;
2-Determining concentration of a wide range of distances at sectorama from 0° to 360° with angle of vertical scanning from 5° to 10°;
3-Remote measurement of ambient air pollution parameters does not affect production processes;
4-Dislocation of Lidar complexes control modules in conditionally single location with unlimited access of specialists to equipment;
5-Provision of outside complexes' modules with spark suppression system;
6-System minimum dependence on climatic conditions during measurements;
7-Online processing of data on spatial spread of pollutant concentrations with displaying results of the measurements in tabulated and graphic formats 2D and 3D;
8-Automatic adjustment (verification) of Lidar complexes;
9-No necessity in backup set of equipment;
10-Ability to additionally use Lidar complexes for a wide range of application in the area of ambient air pollution control;
11-Control of the situational forecast of spreading explosive substances in critical zones in case of emergency;
12-Monitoring of flare emissions with calculation of situational forecast of contamination propagation;
13-Monitoring of leaks at trunk lines.
14-Independence from regular power supply failures.

Negative aspects of the system
1-Individual engineering design of Lidar complexes with deadlines of system implementation is 25-30 months;
2-Necessity in provision of all personnel operating at the oilfield including SPZ aquatic area with anti-IR coating glasses to avoid the risk of impact on visual organs;
3-Holding individual procedures on attestation or confirmation of measurement tool type - Lidar complex within the technical regulation standards;
4-High cost of Lidar complex manufacture and implementation.

CONCLUSION
The concepts of AACC systems at offshore facilities using stationary observation complexes at artificial islands (platforms) and unmanned aerial vehicles have a number of major deficiencies for the following key technical conditions:
1-High production costs of artificial islands development for stationary complexes;
Necessity to develop independent power supply systems for stationary complexes when they are dislocated at artificial islands;
2-Additional costs of backup equipment for the systems using stationary complexes and UAV;
3-Single-point measurement of contaminants at stationary complexes and mobile stations using UAV;
4-Insufficient sensitivity in detecting concentrations by the contaminant control module as a part of the UAV;
Impossibility to use UAV in continuous 24h mode, and considering this, insufficient level of live data;
5-Risks of UAV movement safety in the oilfield aquatic area, necessity to allocate safe "corridors", suspension of

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measurements when approaching-flying off helicopters, during night-time or in case of unfavorable climatic conditions using UAV;

Matrix of comparative analysis of priority system identification of ambient air control for implementation at offshore facilities

Conformities in system control / **Concepts control systems**	Temporary modes **of measurements, efficiency of forecast**	Detection limit of contaminants		Areal coverage with monitoring	Impossibility of results perversion	Uninterrupted data transmission	Safe operation of mobile vehicles	**Explosion safety**	**Restrictions by climatic conditions**	**No necessity in backup sets**	Uninterrupted power supply of control systems	Provision of measurement tools with technical regulation	Total number of scores
Control system using UAV	**4**	**4**		**2**	**2**	**4**	**4**	**2**	**4**	**2**	**2**	**4**	**34**
Control system using stationary complexes	**2**	**0**		**2**	**2**	**4**	**2**	**4**	**0**	**0**	**2**	**4**	**18**
Control system using Lidar complex	**4**	**4**		**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**0**	**40**

Conformity gradation	in scores	in color
conforms	4	green
partially conforms	2	yellow
does not conform	0	red

6-Risk of UAV loss with equipment installed in case of emergency or strong wind.

7-Considering the above shortcomings of the AACC systems based on the concepts of stationary complexes construction or UAV application, a system of organizing a distant control of ambient air using stationary Lidar complexes was determined as the most acceptable for implementation. With this system, a high reliability and informative value of the system is ensured in continuous mode to control the distribution of contaminants excluding the safety criteria risks and valuable production-logistical expenses from the alternative concepts.

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