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Twenty seven years later: methane seepage around failed wells at Kumzhinskoye gas condensate field, Nenets autonomous district, Russia

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Summary

The present paper investigates methane seepages around several cratered wells in the gas condensate field. Methane concentrations in this area appear to be independent of the surface cover and exhibits extremely high spatial variability. In contrast, methane concentrations in the undisturbed marshy floodplains are both lower and less spatially variable. While circumstantial evidence points to a connection between decades old emergency at gas condensate well and methane seepage, the exact mechanism is yet to be exposed.

Introduction

An exploratory drilling at Kumzhinskoye gas condensate field was abruptly interrupted in 1980, when blowout at well №9 prompted a large fire. This caused cratering of this well, as well of three adjacent wells. In order to block the failed well and to stop uncontrolled release of hydrocarbons, a 37kt nuclear device was detonated in 1981 in the inclined well drilled specifically for this purpose (VNIIEF , 1997). However, shortly after an explosion the release of hydrocarbons from the failed wells resumed (Yablokov, 2003). Eventually, the flow of the hydrocarbons in the failed wells was stopped after series of relief well attempts. Afterwards, the berm was constructed around cratered wells to limit the contamination of the surrounding territory. Additionally, the adjacent river branch was dammed from two sides to isolate the contaminated segment. At present, this area falls within the boundaries of the Nenets nature reserve established in 1997.

Following the reports about hydrogen sulphide seepage around the cratered wells, the field investigation was conducted in June 2008 with a purpose to localise seepage areas and collect information regarding its possible sources.

Study site

The study area is located nearly 200 km north of the arctic circle in the Pechora river delta (Fig. 1), which forms a characteristic braided river system. The individual channels in the area are tens to hundreds metres wide even during the baseflow stage of the river. They are separated by the different levels of the floodplain featuring herb- and willow-dominated communities. Additionally, there is a remnant of a river terrace overlooking the floodplain with lichen-dominated vegetation.

The recent geological history of the area includes multiple quaternary glaciations (Lavrov and Potapenko, 2005) with marine transgressions during interglacial periods (Pavlidis et al, 2007) bringing respectively glacial and marine sediments. At present, wide floodplains of the Pechora river valley favour accumulation of fine alluvial sediments (Isachenko, 1985). Unlike surrounding uplands, river valley features only discontinuous permafrost cover with permafrost thickness less than 25 m (Ershov, 1988).

Materials and methods

In order to evaluate hydrogen sulphide concentrations in soil the shallow boreholes were manually augered to a depth of 40 cm. Then the outflow was closed for a minute to let air in the borehole equilibrate with the soil air. Afterwards, the air from a borehole was pumped through a gas analysis apparatus with electrochemical hydrogen sulphide sensor and infrared methane sensor.

In total, gas survey was conducted at 70 points, both in the vicinity of the failed wells and outside of its zone of influence. In the latter case the measurements were performed in the habitats typical for the area: different levels of floodplain as well as elevated river terrace.

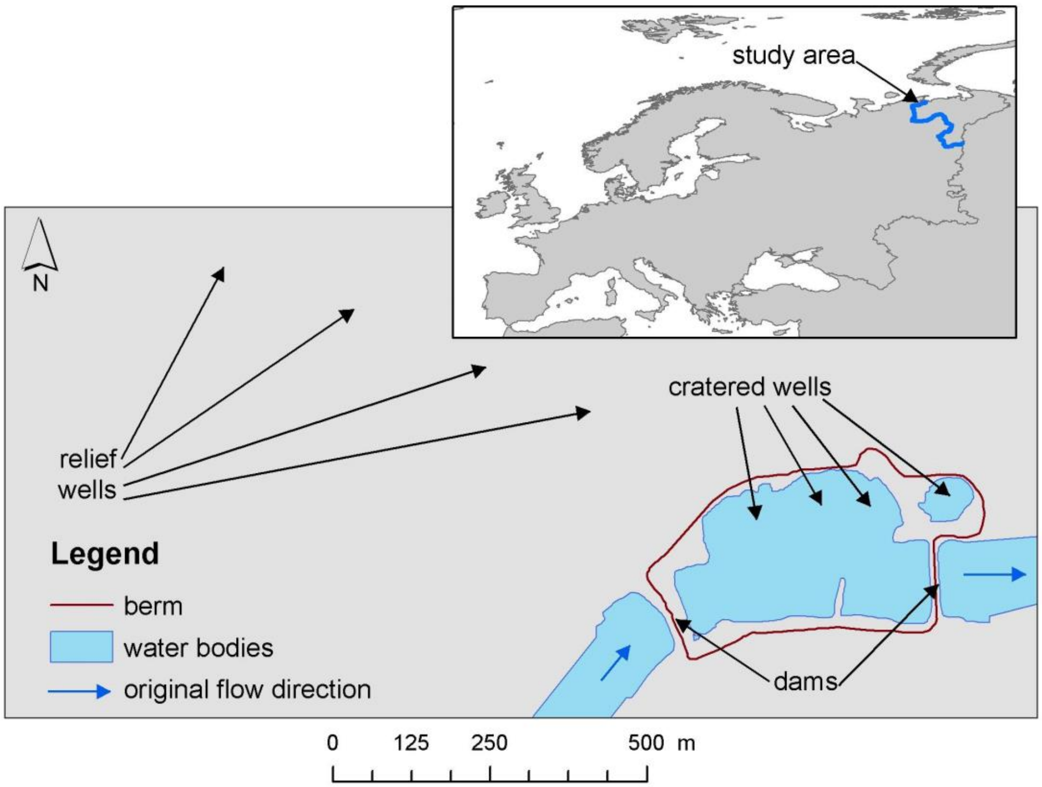

Fig.1 Dammed segment of the river branch. Inset shows location of the Pechora river and the study area.

Results and discussion

There was no detectable hydrogen sulphide at all measurement points. In contrast, methane was found both in the vicinity of the failed wells and in the undisturbed settings. In the latter case the methane was found in the marshy areas in the two floodplain sites. The volumetric concentration of methane in the said areas was 0.35 и 0.19% respectively and varied little between measurement points.

The distribution of the methane near failed wells was strikingly different. There was extremely high spatial variability with methane concentration varying from undetectable to more than 5% (upper measurement limit) at sampling points merely 2 m away from each other (Fig. 2). Also, unlike the undisturbed settings, there was no clear link between methane presence and soil properties. The methane was found both in vegetation-free dam and within grassed floodplain. Furthermore, there were multiple “bubbling” points within flooded areas, where gas bubbles were leaving underlying sediments. In some places on land similar phenomenon caused a formation of geyser-like features several tens of centimetres in diameter around the bubbling points. In general the detected levels of methane were roughly an order of magnitude higher than in the undisturbed settings with median detected concentration of 2.9%. Another methane release point was found at the casing head 800 m north-west of the failed wells.

While the employed method did not allow to directly evaluate methane concentrations in the soil air and associated methane flux, it allowed to do semi-quantitative comparisons of different settings within the study area. One may conclude, that there is significant positive anomaly of methane concentrations around failed wells. Several possible sources of the surplus methane in the area need to be discussed:

1. Decomposition of the hydrocarbons accumulated in sediments during the well failure.
2. Favourable conditions for the methanogenesis around failed well unrelated to contamination.
3. Methane seepage from the permafrost and underlying strata.

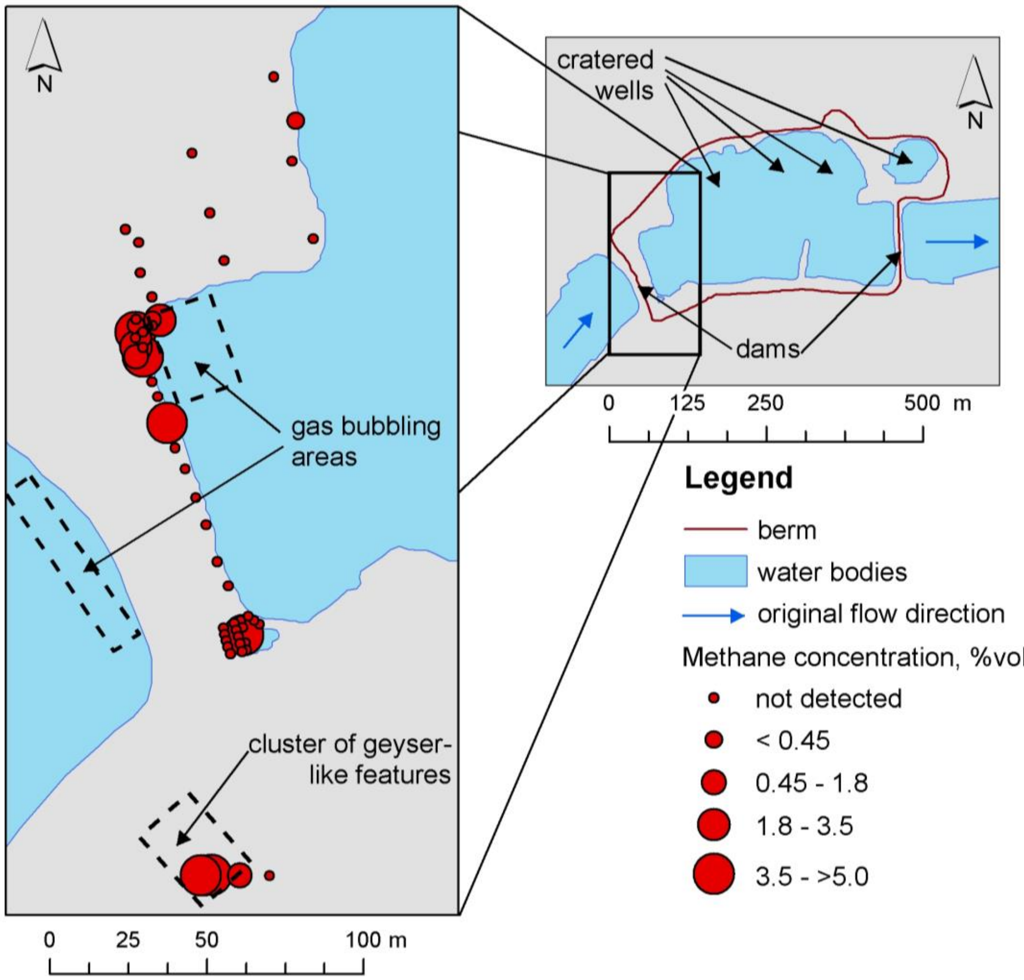

Fig. 2 Methane seepage around failed wells.

The methanogenesis was indeed reported to occur at a number of contaminated sites (e.g. Fischer et al., 2004). Previous studies indicate that there were more than 30 tonnes of hydrocarbons accumulated in the bottom layer and sediments of the dammed segment of a channel (SBNE, 2001). Consequently, one may indeed theorise that the decomposition of the contaminants may cause observed anomaly. However, number of observations directly contradicts this suggestion. Some of the geiser-like features are located upstream of the dammed segment, where the hydrocarbon contamination is highly unlikely. Also, the existence of the said features itself contradicts the first hypothesis, as areal contamination of the bottom sediments is expected to cause areal release of methane.

The second hypothesis deals with indirect factors affecting the methane production and transport in the soils. The mechanical disturbance of soils in Arctic often causes a thickening of the active layer, which may facilitate a methane release (Badu et al., 2006). Extreme conditions restrict the diversity of methanotrophic organisms, which may limit the methane utilisation rate under changing conditions (Liebner et al., 2009).

However, the high spatial variability of the methane concentrations within homogeneous settings undermines the importance of this factor.

The methane seepage in the oil and gas fields may occur naturally (Ryl'kov et al., 1996), during the well failures (Zinchenko et al., 2008), or due to a compromised integrity of the overburden (Badu et al., 2006). The absence of the clear connection between surface conditions and methane release is clearly consistent with either possibility. Moreover, the methane migration through the fractures (natural or anthropogenically induced) explains the existence of the methane release points and associated geyser-like features. In this case high spatial variability of the methane concentrations indicate that the localised migration pathways come close to the surface. The absence of such features in other parts of the floodplain may be treated as a circumstantial evidence of the connection between the well emergency and methane seepage.

Conclusions

There is a pronounced positive anomaly of the methane in soils of Kumzhinskoye gas condensate field in the failed wells area. The methane release zone extends beyond the area contaminated by the hydrocarbons during well failure. The possible cause of the focussed methane release is its migration from the permafrost or underlying sediments through the fractures associated with either emergency itself or subsequent contingency measures.

The methane release hundreds of metres from the failed well and long after the well was secured illustrates possible long-term risks associated with oil and gas exploration. For example, it may cause an accumulation of methane in the shallow sediments or beneath river ice in winter. In such case, single large release prompted by the mechanical stress from heavy machinery may cause dire consequences. While this possibility is of little relevance in the study area due to its nature reserve status and its remoteness, it needs to be considered in the populated areas or during reactivation of the old drilling sites.

Acknowledgements

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References

Badu, Yu. V., Gafarov, N. A., Podborny, E. E. (Eds.), 2006 Kriosfera neftegazokondensatnyh mestorozhdeniy poluostrova Yamal. Tom 1 Kriosfera Haraseveyskogo gazokondensatnogo mestorozhdeniya. Nedra, Moskva, 347 p. (In Russian)

Ershov, E. D. (Ed.), 1988. Geokriologiya SSSR. Kniga 1 Evropeyskaya territoriya SSSR. Nedra, Moskva, 538 p.

Fischer, A., Vieth, A., Knoller, K., Wachter, T., Dahmke, A., Richnow, H., 2004. Charakterisierung des mikrobiellen Schadstoffabbaus mithilfe von isotopenchemischen Methoden. Grundwasser 9, 3, pp.159-172 (In German)

Isachenko, A. G., 1985. Landshafty SSSR. Izdatel'stvo LGU, Leningrad, 320 p. (In Russian)

Lavrov, A. S., Potapenko, L. M., 2005. Neopleystotsen severo-vostoka Rysskoy ravniny. Aerogeologiya, Moskva, 222 p. (In Russian)

Pavlidis, Yu. A., Nikiforov, S. L., Ogorodov, S. A., Tarasov, G. A., 2007. The Pechora Sea: Past, recent, and future. Oceanology 4, 6, pp. 865-876

Ryl'kov, A. V., Gushchin, V. A., Silich, V. E., Zavatskiy, M. D., 1996. Problemy razvitiya pryamyh geohimicheskih metodov poiska skopleniy uglevodorodov v Zapadnoy Sibiri, in: Ryl'kov, A.V. (Ed.) Ispolzovanie geohimicheskoy informatsii pri prognose neftegazonosnosti. Tyumen', pp. 84-95 (In Russian)

SBNE, 2001, Razrabotka I realizatsiya programmy lokalizatsii i likvidatsii zon neftezagryazneniya pochv, gruntov i donnyh osadkov Kumzhinskoy ploshchadi. Kniga 1. Sankt-Peterburg, 205 p. (In Russian)

VNIIEF , 1997. Yadernye ispytaniya SSSR. Tom 1 Tseli, obtshie harakteristiki, organizatsiya yadernyh ispytaniy., Sarov, 1997 (In Russian)

Yablokov, A. V., 2003. Mif o bezopasnosti i effektivnosti mirnyh podzemnyh yadernyh vzryvov. TsEPR, Moskva, 176 p. (In Russian)

Zinchenko, A. V., Paramonova, N. N., Privalov, V. I., Reshetnikov, A. I., Titov V. S., 2008. Estimation of methane sources from concentration measurements in the area of gas production in the north of Western Siberia. Russian Meteorology and Hydrology, 33/1, pp.34-42