

Ecological study of gas fields in the northern Adriatic

1. Preface

This review presents the results of environmental studies in the northern Adriatic carried out for special purposes, that is the possible exploitation of gas fields. The survey is based on the data collected within the special project for national gas oil company INA - Naftaplin and includes processing of formerly collected data, than data from research platforms in 1978-1986, as well as the results of field work carried out for this purpose in 1984, 1985 and 1986.

with this company, meteorological and oceanographic characteristics have been measured at all research platforms in the Adriatic since 1970. Currents at three levels, waves and wind were permanently measured. In climatic terms (3 times a day) pressure, air temperature and humidity, vertical distribution of sea temperature with batitermograph were measured and sea water samples were taken for determining salinity. This was organized by the State Hydrographic Institute together with the

Institute of Oceanography and Fisheries. The major part of data in this paper originates from that source. INA-Naftaplin also ordered two projects:

1. Hydrographic and oceanographic research for the exploitation of gas in the northern Adriatic, 1985. This project was carried out by the Institute of Oceanography and Fisheries, Split, State Hydrographic Institute, Split and Geofizika, Zagreb. The project manager was dr. Mira ZORE-ARMANDA, project coordinator dr. Ivo NOŽINA.

2. Environmental study of the actual state in the northern Adriatic - gas field IVANA, 1986. The project was realized by the Institute of Oceanography and Fisheries, Split, State Hydrographic Institute, Split, "Jožef Stefan" Institute Ljubljana and "Ruder Bošković" Institute, Center for Marine Research, Zagreb. The project coordinator was dr. Mira ZORE-ARMAN-

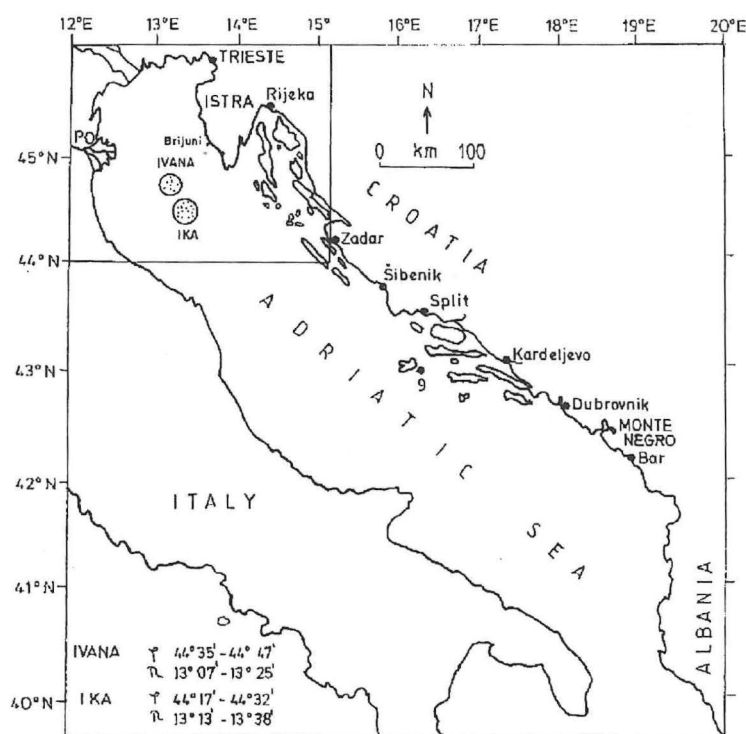


Fig. 1.1. The Adriatic Sea and the schematically marked areas of the IVANA and IKA fields and locations mentioned in the paper

The investigated area includes gas fields IVANA and IKA (Figs 1.1 and 1.2) in the region of the northern Adriatic. INA-Naftaplin carried out research in this area using two research platforms. Based on the agreement

with this company, meteorological and oceanographic characteristics have been measured at all research platforms in the Adriatic since 1970. Currents at three levels, waves and wind were permanently measured. In climatic terms (3 times a day) pressure, air temperature and humidity, vertical distribution of sea temperature with batitermograph were measured and sea water samples were taken for determining salinity. This was organized by the State Hydrographic Institute together with the

DA, Hydrographic Institute coordinator dr. Ivo NOŽINA.

For the purpose of these projects, field work in the area of the gas fields was done in December 1984, May 1985, December 1985 and March 1986. The research ships ANDRIJA MOHOROVIČIĆ and BIOS took part. This presentation sets forth the essential parts of the given projects that deal with the ecological problems of the area. The geodesic and geophysical data collected in the suggested area of the gas pipeline from the IVANA field to cove Štinjan are not presented in this review.

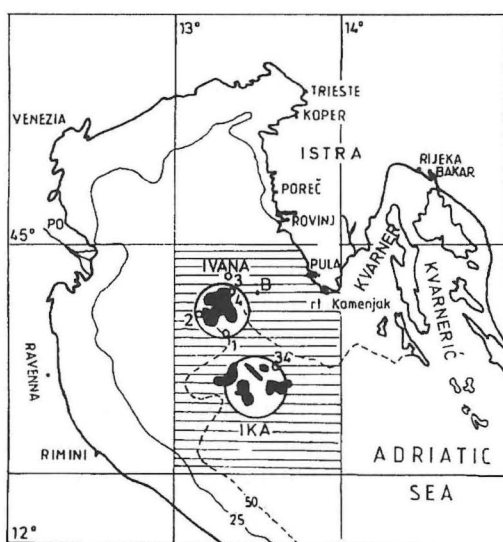


Fig. 1.2. The IVANA and IKA gas fields are marked with shaded areas. Schematically the gas fields are marked with circles. The wider area within $\varphi = 44^\circ - 45^\circ$ and $\lambda = 13^\circ - 14^\circ$ is hatched (Marsden square 179 (43)). Another four stations (1-4) where various samples were collected in March 1986 are marked, as well as station 34 of the ANDRIJA MOHOROVIČIĆ expedition.

Fig.1.2. shows a ground plan of the gas fields and their area is presented schematically with circles. Four sampling stations are marked, as well as station 34 of an earlier expedition ANDRIJA MOHOROVIČIĆ.

All available historical data of the data bank of the State Hydrographic Institute and Institute of Oceanography and Fisheries were used to describe various properties in this report. They date from the period of 1911 onwards. In Fig.1.2 the area (Marsden square

179 (43)) for which the data from the data bank were used, is hatched.

The composition of natural gas from the gas fields is methane (CH_4), nitrogen (N_2) and carbon dioxide (CO_2). Alone it cannot pollute the environment, except in case of explosion or fire. As gas oil (diesel fuel) is to be used as power-generating fuel during exploitation, it should be managed with care since the area is located in a zone that is exposed to pollution.

The highly developed industry and agriculture of northern Italy accounts for large quantities of waste waters, that enter the Adriatic mainly via the Po River. Anthropogenic effects, according to the manner of the increasing organic matter in marine ecosystems, have two different aspects. Thus, part of the increased organic matter under marine environmental conditions is rather quickly metabolized rendering possible an increase of marine biological production. The second aspect is far more dangerous, since some specific organic substances entering the marine environment may exert very harmful effects to a series of biological, geochemical and physical processes causing drastic ecological disturbances of both local and wider regional extent, due to their toxicity, persistence and mass. Aside from being affected by waste waters from land, the studied area is located in the region of intensive maritime activities, therefore oil and oil derivatives are a permanent source of pollution. Discharge of bilge waters or washing of tanks are particularly dangerous. For these reasons that area is particularly sensitive to pollution. To estimate the level of sea water pollution, aside from other things, contents of dissolved organic matter and polycyclic aromatic hydrocarbons in sea water were analyzed, while the contents of aromatic and polyaromatic hydrocarbons, as well as chlorinated hydrocarbon derivatives were determined in sediments and marine organisms.

The whole paper is divided into chapters according to groups of parameters as follows: climatic characteristics, waves, circulation,

dynamic model, tides, thermohaline and optical properties, nutrient salts and content of oxygen, heavy metals, and macroconstituents organic pollutants, pelagic and benthic communities and toxicological tests.

The main climatic properties were analyzed from the data collected from platforms and surrounding area.

For the analysis of surface waves, the data of the wave recorder from the 1978-1984 period were used, as well as data from 1985-1986.

Currents were measured from research platforms with autonomous current meters, and at fixed intervals drift cards were launched into the sea.

The effect of wind on current was separately analyzed by means of a dynamic model.

Data on low and high tides on the western coast of Istria are presented.

Thermohaline and optical factors (temperature, salinity, density, transparency, turbidity and the color of sea) were determined according to platform measurements (daily measurements with batitermograph and determining salinity) as well as by earlier measurements from the gas fields area.

The results of oxygen and nutrient salts content are presented from historical data from the gas fields area.

The content of heavy metals and macroconstituents in sea water is determined for the IVANA field, as well as the content of heavy metals in fish and shellfish for the area IVANA field - cove Štinjan near Pula.

To estimate the level of pollution of sea water, marine organisms and sediments with organic pollutants in the IVANA field, the content of dissolved organic matter, polycyclic aromatic hydrocarbons (PAH), chlorinated hydrocarbons and volatile phenols were analyzed. The research focused on the qualitative and quantitative determining of polyaromatic hydrocarbons in different media, that could be endangered during future exploitation.

Pelagic communities are also partly presented based on historical and statistical data.

Owing to their behavior, organisms of this community were considered in a larger area, so that a better understanding of the areas of IVANA and IKA gas fields could be given.

Data on the spatial-temporal distribution of primary production, chlorophyll *a* concentrations, zooplankton and bacterioplankton are given. The principal species of small pelagic fish (sardine, sprat, anchovy) were studied according to the seasonal-spatial distribution and their concentrations.

The qualitative and quantitative contents, as well as the distribution of complete benthic settlements were studied. The research covered phytobenthic and zoobenthic settlements, in the coastal rocky areas and mobile bottoms of the open area, and particularly ichthyobenthic settlements in the deeper mobile bottoms of the wider area of the IVANA field. The effect of sea water pollution on phytobenthic settlements in the coastal part of the studied area was analyzed.

Toxicological tests of the mussel were performed.

The northern Adriatic has been studied since the mid-19th century (see ZAVODNIK D., 1983). Italian scientists particularly investigated the western part of the northern Adriatic, the Po River estuary and its influence on hydrographic and biological characteristics of the area. In the last few decades the open area of the northern Adriatic has been the focal point of intensive research carried out by the collaborators of the Center for Marine Research of the Institute Ruder Bošković in Rovinj, expeditions of the research ship ANDRIJA MOHOROVIČIĆ, as well as participants of a number of international bilateral projects. The results of such intensive survey have been partly presented in this review.

It has already been pointed out that this review was completed for special purposes. Since the presented new data, as well as earlier facts may be useful for a large number of experts interested in this topic, they have been published. We also suppose that the gas fields will sooner or later be exploited, therefore the

knowledge of the actual state as well as the knowledge of dynamic factors necessary for safe work at sea, will be useful.

Each chapter presents a whole, yet the results are coordinated. As an easy reference for everyone who might be interested in this topic, there is an extensive summary at the end of the paper presenting all important conclusions and data from each chapter.

Editor:

dr. Mira ZORE-ARMANDA

1.1. REFERENCES

- ANDRIJA MOHOROVIČIĆ, (1974-1976.)
1982. Izvještaj i rezultati oceanografskih istraživanja Jadranskog mora. Hidrografski Institut RM Split. 239 pp.
- ZAVODNIK, D. 1983. 400 years of the Adriatic marine science. *Thalassia Jugoslavica*, 19(1-4): 405-429.

Ekološka studija plinskih polja u sjevernom Jadranu

Predgovor

U ovom se prikazu iznose rezultati ekoloških istraživanja u dijelu sjevernog Jadrana izvršenih zbog posebne namjene, tj. moguće eksploatacije plinskih polja. Prikaz se bazira na gradi projekata za INA-Naftaplin, a obuhvaća obradu ranije prikupljenih podataka, zatim podataka prikupljenih sa istraživačkih platformi 1978. - 1986. g., kao i rezultata terenskog rada izvršenih za ovu namjenu u toku 1984., 1985. i 1986. godine.

Područja istraživanja su plinska polja IVANA i IKA (Sl. 1.1. i 1.2.) u regiji sjevernojadranskog shelfa. Poduzeće INA-Naftaplin je istraživalo to područje sa dvije istraživačke platforme. Na osnovu sporazuma sa tim poduzećem, od 1970.g. nadalje mjerili su se meteorološki i oceanografski elementi sa svih istraživačkih platformi na Jadranu. Kontinuirano su mjerene morske struje na tri razine, valovi vjetra i vjetar. U klimatskim terminima (3 x dnevno) su mjereni tlak, temperatura i vlaga zraka, vertikalni raspored temperature mora batitermografom i uzimani uzorci mora za određivanje slanosti. Mjerenja je organizirao Državni hidrografski institut u suradnji s Institutom za oceanografiju i ribarstvo. Najveći dio fonda podataka u ovom prikazu potječe iz tog izvora. INA-Naftaplin je nadalje

naručila dva projekta:

1. Hidrografska i oceanografska istraživanja za eksploataciju plina u sjevernom Jadranu, 1985. Projekt su izveli Institut za oceanografiju i ribarstvo, Split, Državni hidrografski institut, Split i Geofizika, Zagreb. Voditelj projekta dr. Mira ZORE-ARMANDA, koordinator projekta dr. Ivo NOŽINA.

2. Ekološka studija nultog stanja sjevernog Jadrana - plinsko polje IVANA, 1986. Projekt su izveli Institut za oceanografiju i ribarstvo, Split, Državni hidrografski institut*, Split, Institut "Jožef Stefan", Ljubljana i Institut "Ruder Bošković", Centar za istraživanje mora, Zagreb. Koordinator projekta dr. Mira ZORE-ARMANDA, koordinator za Državni hidrografski institut dr. Ivo NOŽINA.

Za potrebe ovih projekata izvođen je u području plinskih polja terenski rad u prosincu 1984. godine, svibnja 1985.g, prosincu 1985.g. i ožujku 1986. g. Učestvovali su istraživački brodovi "ANDRIJA MOHOROVIČIĆ" i "BIOS". Sadašnji prikaz daje bitne dijelove iz navedenih projekata, koji se odnose na ekološku problematiku podmorja. Rezultati geodetskih i geofizičkih mjerenja izvršenih na

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predloženoj trasi plinovoda od polja IVANA do uvale Štinjan nisu uneseni u ovaj prikaz. Na Sl.1.2. prikazan je tlocrt plinskih polja i shematski je njihovo područje prikazano krugovima. Označene su 4 postaje na kojima su sabrani razni uzorci, kao i postaja 34 ranije ekspedicije "ANDRIJA MOHOROVIČIĆ". (1976-1976).

Za opis raznih svojstava u ovom prikazu korišteni su i svi raspoloživi povjesni podaci pohranjeni u bankama podataka Državnog hidrografskog instituta i Instituta za oceanografiju i ribarstvo. Podaci se odnose na razdoblje od 1911. g. nadalje. Na Sl. 1.2. je crtkano označeno područje (Marsdenov kvadrat 179 (43) za koje su korišteni podaci iz banke podataka.

Sastav prirodnog plina s plinskih polja je metan (CH₄), dušik (N₂) i ugljik dioksid (CO₂). On po sebi ne predstavlja opasnost za okoliš, osim u slučaju eksplozije i požara. U eksploataciji bi se koristilo plinsko ulje (diesel gorivo) za pogon postrojenja. Međutim, područje je već samo po sebi u vrlo izloženoj zoni.

Razvijena industrija i poljoprivreda sjeverne Italije daje velike količine otpadnih voda, koje su u Jadran slijevaju prvenstveno rijekom Po. Antropogeno djelovanje, prema načinu unošenja organskih tvari u morski ekosistem, očituje se u dva različita aspekta. Prvo je unošenje hranjivih organskih tvari koje se u uvjetima morske sredine relativno brzo metaboliziraju i omogućuju povećanje bioprodukcije mora. Mnogo opasniji je drugi aspekt, kada u morsku sredinu ulaze neke specifične organske tvari, koje zbog svoje toksičnosti, perzistentnosti ili mase mogu pogubno djelovati na niz bioloških, geokemijskih i fizikalnih procesa, izazivajući drastične ekološke poremećaje, kako lokalnih tako i širih regionalnih razmjera. Istraživano područje je, osim pod utjecajem otpadnih voda s kopna, također i u zoni razvijenog pomorskog prometa, pa je izloženo opasnosti od zagađivanja naftom i naftnim derivatima, a opasno je i ispuštanje kaljužnih voda ili pranje tankova. Zbog toga je to područje posebno ugroženo zagađivanjem.

Da bi se ocjenila razina onečišćenja mora, uz ostalo je analiziran sadržaj otopljene organske tvari i policikličkih aromatskih ugljikovodika u morskoj vodi, a sadržaj aromatskih i poliaromatskih ugljikovodika, te kloriranih derivata ugljikovodika određivan je u sedimentu i morskim organizmima.

Cijeli prikaz je podijeljen u poglavlja prema grupama parametara kako slijedi: klimatske osobine, vjetrovni valovi, strujanje, dinamički model, morske mijene, termohalina i optička svojstva, hranjive soli i sadržaj kisika, teški metali, organska zagađivala, pelagijske i bentoske zajednice, te toksikološki testovi.

Obrađeni su osnovni klimatski elementi na osnovi podataka sa platformi i neposredne okoline.

Za analizu površinskih valova korištene su registracije valografa u periodu do 1978-1984.g., s dopunjenim registracijama iz 1985-1986.g.

Morske struje su mjerene s istraživačkih platformi autonomnim strujomjerima, a u određenim vremenskim razmacima bacane su u more i kartice.

Utjecaj vjetra na strujanje posebno je ispitan pomoću modela.

Iznoseni su podaci o visini visokih i niskih voda na zapadnoj obali Istre.

Temperatura, slanost, gustoća, prozirnost, turbiditet i boja mora su određeni na osnovu mjerenja s platformi (dnevna mjerenja batitermografom i određivanje slanosti) kao i ranijih mjerenja u zoni plinskih polja.

Prikaz sadržaja kisika i hranjivih soli dat je prema povjesnim podacima iz zone plinskih polja.

Sadržaj teških metala i makrokonstituenata u morskoj vodi određen je za polje IVANA, a sadržaj teških metala u ribama i školjkama iz poteza polje IVANA - uvala Štinjan kod Pule.

Da bi se procijenila razina onečišćenja morske vode, morskih organizama i sedimenta s organskim zagađivalima na polju IVANA je analiziran sadržaj otopljene organske tvari, policikličkih aromatskih ugljikovodika (PAH),

kloriranih ugljikovodika i hlapivih fenola. Težište istraživanja je postavljeno na kvalitativnom i kvantitativnom određivanju poliaromatskih ugljikovodika u različitim medijima, koji bi mogli biti ugroženi kod buduće eksploatacije.

Pelagijske zajednice su prikazane dijelom i na osnovu povjesnih i statističkih podataka. Radi svojeg načina života organizmi ove zajednice promatrani su u širem prostoru, kako bi se moglo bolje definirati područje plinskih polja IVANE i IKE. Doneseni su podaci o vremenskoj i prostornoj raspodjeli primarne proizvodnje, koncentraciji klorofila *a*, zooplanktona i bakterioplanktona. Glavne vrste male pelagične ribe promatrane su s obzirom na sezonsko-prostorno kretanje odnosno njihove koncentracije.

Ispitani su kvalitativni i kvantitativni sastavi te rasprostranjenost cjelovitih bentoskih naselja. Istraživanjima su obuhvaćena fitobentoska i zoobentoska naselja, koja su razvijena na priobalnom stjenovitom i otvorenijem pomičnom dnu, te posebno ihtibentoska naselja na dubljem pomičnom dnu šireg područja polja IVANA. Analiziran je učinak onečišćenja mora na fitobentoska naselja u priobalnom dijelu istraživog područja.

Izvršeni su toksikološki testovi na dagnji.

Sjeverni Jadran je istraživao od sredine prošlog stoljeća (vidi na pr. ZAVODNIK D. 1983). Talijanski istraživači su posebno obradili zapadni dio sjevernog Jadrana, te estuar rijeke Po i njezin utjecaj na hidrografska i biološka svojstva područja. U posljednjim decenijama otvoreni sjeverni jadrani intenzivnije istražuju suradnici Centra za istraživanje mora Instituta Ruder Bošković u Rovinju, ekspedicije istraživačkim brodom ANDRIJA MOHOROVIČIĆ, te suradnici u nizu međunarodnih bilateralnih projekata. Rezultati tih istraživanja su dijelom korišteni u ovom pregledu.

Već je napomenuto da je ova studija izrađena za posebne namjene. Ipak smatramo da izneseni novi podaci i prikaz ranijih saznanja mogu biti korisni za širi krug zainteresiranih stručnjaka, te ih zbog toga objavljujemo. Osim toga pretpostavljamo, da će se plinska polja prije ili kasnije aktivirati, pa će poznavanje tzv. O-tog stanja, kao i poznavanje dinamičkih čimbenika nužnih za siguran rad na moru, biti korisno.

Svako poglavlje predstavlja cjelinu za sebe, ali su rezultati međusobno usklađeni.

Zbog lakšeg korištenja studije od strane šireg kruga korisnika, na kraju prikaza dat je opširan sažetak u kojem su izneseni svi glavni zaključci i podaci iz pojedinih poglavlja.

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