"Surveyor": An underwater system for threat material detection

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The bottoms of the coastal seas, and oceans as well, are contaminated by many man-made objects including a variety of ammunition. This contamination is world wide spread with some areas being highly polluted presenting a serious threat to local population and to visitors as well. All littoral nations are investing lots of effort into the remediation of their coastal areas.

Once the presence of the anomaly on the bottom of the shallow coastal sea water is confirmed (by visual identification and by using one or several sensors, namely magnetometer, sonar and optical cameras) it is necessary to establish if it contains explosive/chemical warfare charge. In our work we propose this to be performed by using neutron sensor installed within an underwater vessel – "Surveyor". When positioned above the object, or to its side, the system inspects the object for the presence of the threat material by using alpha particle tagged neutrons from the sealed tube d+t neutron generator.

I. INTRODUCTION

Security is no longer only exclusive part of the military and political spheres, but a complex phenomenon that demands a comprehensive approach, which includes socio-economic and environmental issues. One critical aspect of this integral approach concerns seas and coasts, on which local population relies for sustenance and livelihood options, and which underpins vital economic sectors such as trade, tourism, energy and defence.

In light of this one has to consider all material which has been dumped into the coastal seas or oceans. The dumping of material in the sea waters has a long history. Objects are dumped into the sea in a variety of ways. Sea dumping, as currently defined as any deliberate disposal into the sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures.

The legacy of conflicts which resulted in the world wars and local fightings is especially worysome. Industrialized nations stockpiled record numbers of munitions in preparation for what would become World War I, and later, World War II. With the end of these wars came the urgent need to dispose vast quantities of left over munitions from battlefields around globe. Having limited options and few resources available during the reconstruction period, "dumping at sea" was adopted as the method of choice.

Seas and inland waters used for disposal, weapons development, or "live fire" training, are today littered with the remains of some of the most powerful weapons ever created. These practices continued as we moved into the nuclear age, and radioactive materials have since been added to the mix.

Since the end of World War II, there has been a number of treaties dealing with the limitations, reductions, and elimination of so-called weapons of mass destruction and their transport systems. The easiest and "cheapest" way to "eliminate" chemical weapons and munitions following World War II was to dump them into the oceans. As environmental awareness has increased, and the ecological repercussions of such actions have made them unacceptable, steps have been taken to prohibit the manufacturing and use of chemical weapons. However, questions as to the short and long-term effects, and ultimately the remediation of areas and populations damaged by weapons and munitions dumping, have been largely left alone.

Useless, obsolete, recovered ammunitions, explosives and war material of any sort have been dumped in oceans and seas for decades. Among the military ordnance dumped at sea, chemical weapons (CWs) and riot control agents represent a not negligible percentage. The yearly rate of dumping is slowly diminishing also because of the entry into force of international conventions stimulating the adoption of other disposal practices. However, the actual amount of dumped war material, subject to the corrosive action of sea water which causes the release of chemical products, has to be considered as a relevant source of persistent pollutants in need of in-depth scientific investigations.

Taking into consideration the extension of the dumping sites, the wide dispersion of the dumped war material due to trawling fishery, their increasingly rusted conditions and a number of other factors, there is a need for data and information suitable to provide a sound scientific base to carefully evaluate costs and benefits deriving from possible clean up activities at sea.

Remediation of marine chemical weapons and munitions dumpsites is technically challenging because of the nature of the material dumped and the uncertainty surrounding the quantities, type, locations and the present condition or stability of these materials.

Dumped munitions, and in particular the disturbance of dumped munitions by seabed activities, e.g., fishing, sand and gravel extraction, dredging and dumping operations and the placement of cables and pipelines, is an important issue and should be addressed. It is essential

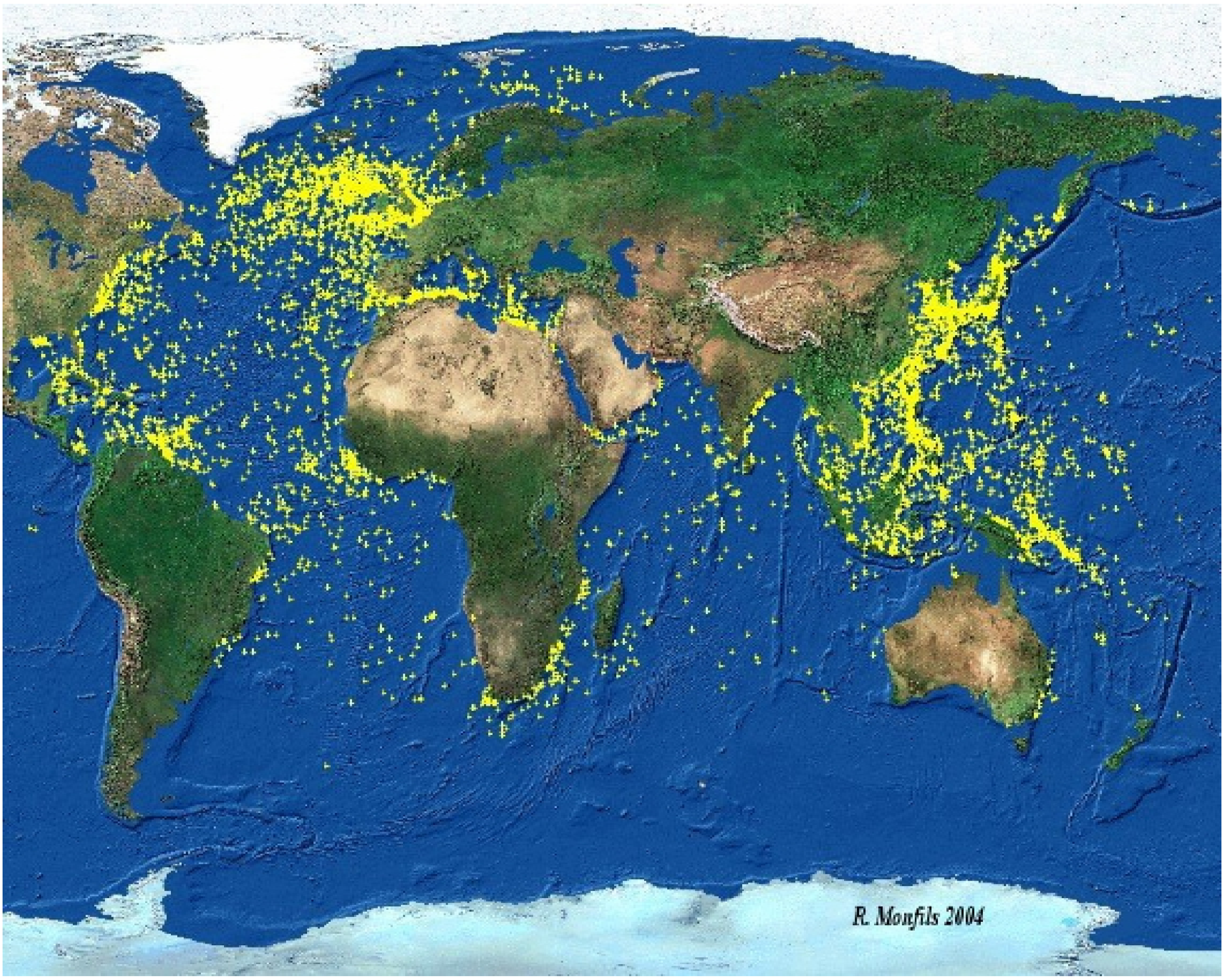

FIG. 1: World War II sunken vessels combining AMIO and SPREP databases (after Monfils, 2005).

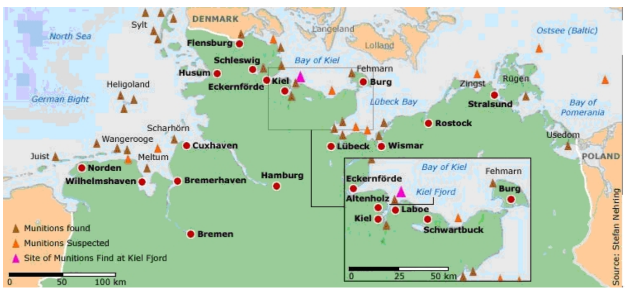

FIG. 2: Munitions graveyards: These sites are known or suspected by authorities to contain old weapons. But experts believe that the affected areas are actually spread across wide swaths of the Baltic Sea. (After A.Bojanowski, A Rusting Timebomb in the Baltic, Der Spiegel, April 04, 2007).

that details of the locations of all munitions dumpsite, and areas where munitions are detected on the seabed be maintained. Any seabed activities to be undertaken within or close to these locations should be subject to a

TABLE I: AMIO & SPREP Shipwreck Databases – Distribution of Shipwrecks Globally.

Ocean/Seas	# Vessels	Total Tonnage	# Tankers
North Atlantic	3002	15108305	452
South Atlantic	198	1143374	20
Mediterranean	305	1578910	19
Indian	313	1813398	35
Arctic	124	729569	2
Pacific	3276	12158895	273

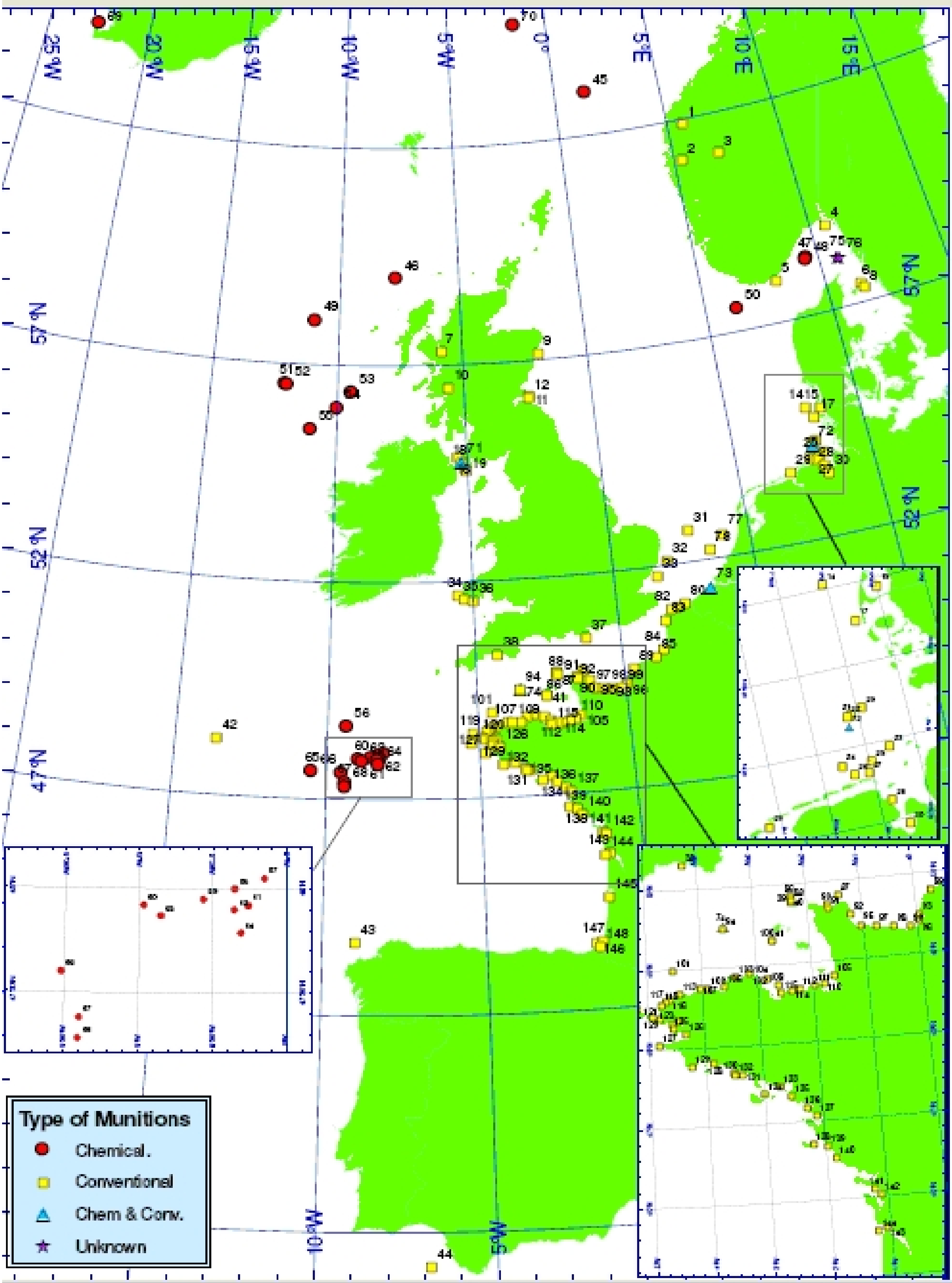

FIG. 3: Locations of munition dumpsites (After OSPAR Commission, 2005).

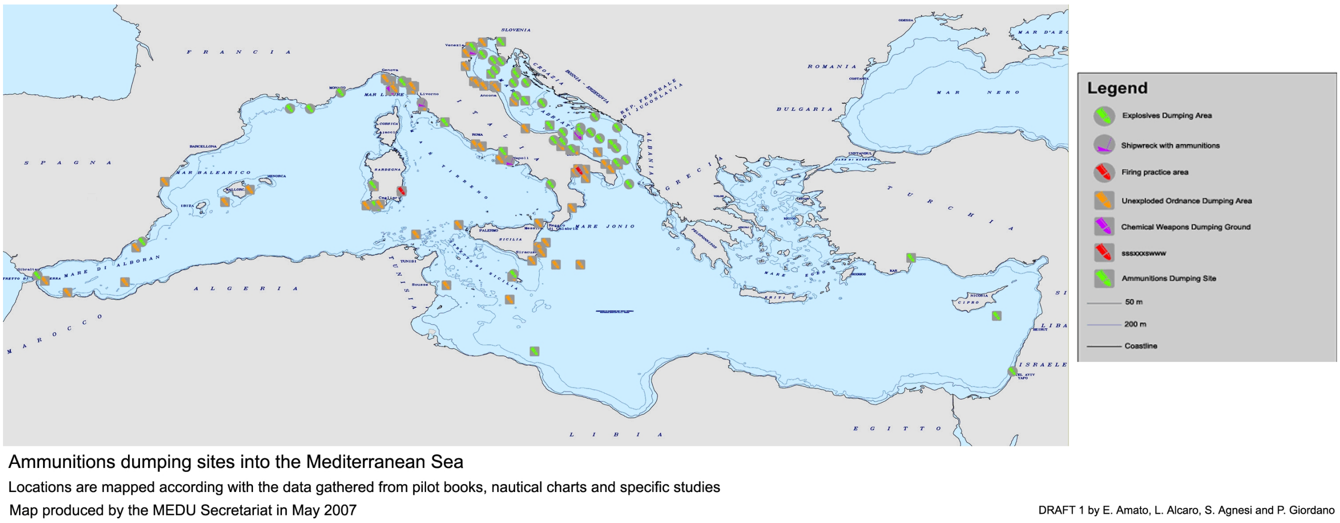

FIG. 4: Reported locations of ammunition on the floor of the Mediterranean.

full assessment of the potential risk prior to the approval of these activities by national authorities.

Many of the materials on the bottom of the seas are due to numerous shipwrecks. The recent efforts include so called SPREP and AMIO databases of WWII shipwrecks. Although work on the Pacific SPREP database is relatively complete, work on shipwrecks in the other oceans has only recently commenced. The Atlantic, Mediterranean and Indian Ocean (AMIO) database of WWII shipwrecks is in its initial stages. Currently, the AMIO database contains over 3953 WWII vessels over 1000 gross tons equating to over 20 million tons of shipping lying on the bottom of the ocean. The distribution of WWII shipwrecks from both databases is shown in Table I and Fig. 1.

Some areas in Europe are of special interest because of large amounts of dumped ammunitions. These include Baltic Sea, Atlantic Ocean and North Sea and Mediterranean. Figure 2 shows the ammunition dumping sites in the Baltic Sea.

Figure 3 shows the locations of munition dumpsites in the area covered by so called OSPAR Commission (Atlantic Ocean and North Sea). Many of the sites are rather close to the shore.

Figure 4 shows the recent effort of UNEP-MEDPOL for the Mediterranean. Of special interest to us is Adriatic Sea. There have been major accidents during the WWII. For example, shortly after the end of World War II, the United States dumped unspecified quantities of phosgene, hydrogen cyanide, and cyanogen chloride bombs in the Adriatic Sea “off the Island of Ischia, near Bari,” from 12 October to 5 November 1945 and from 1-15 December 1945. Unspecified quantities of mustard and/or Lewisite bombs were dumped at the same site from 1-23 April 1946. From 1946 to 1997, medical researchers at the University of Bari detected over 230 cases of exposure to mustard in the Adriatic Sea, most of the cases have been among Apulian trawler fishermen.

More recently the problems are due to the NATO bombs disposed in the Adriatic Sea. In May of 1999 the captain and two sailors on the Profeta, a fishing vessel from the port of Chioggia, were seriously injured when a canister pulled up in a pile of flapping fish exploded and sent shrapnel flying across the deck.

These were the unused bombs that NATO pilots returning to Italian bases from air raids over Yugoslavia sometimes have to dump before landing. NATO has designated six areas in international waters between Italy and the coasts of Croatia, Montenegro, Albania and Greece for the disposal of unexploded bombs (**six sites of eight kilometers’ diameter**). Some bombs have been in place since 1995, when the alliance conducted bombing missions over Bosnia. **The dumping is “obligatory” when: a pilot comes back in an emergency status from a mission, the bomb re-**

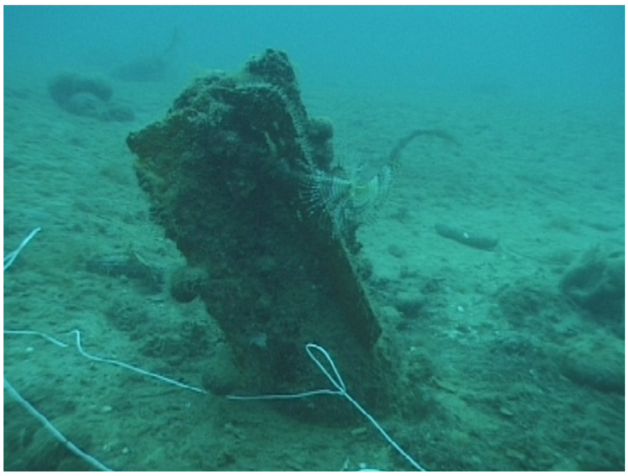

FIG. 5: Ammunition on the sea floor.

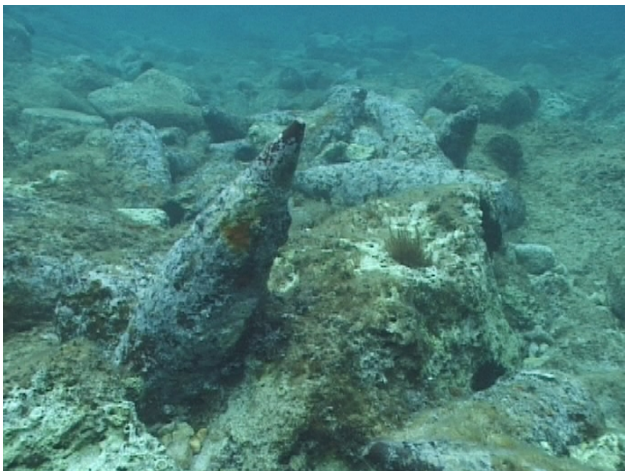

FIG. 6: Different ammunition on the sea floor.

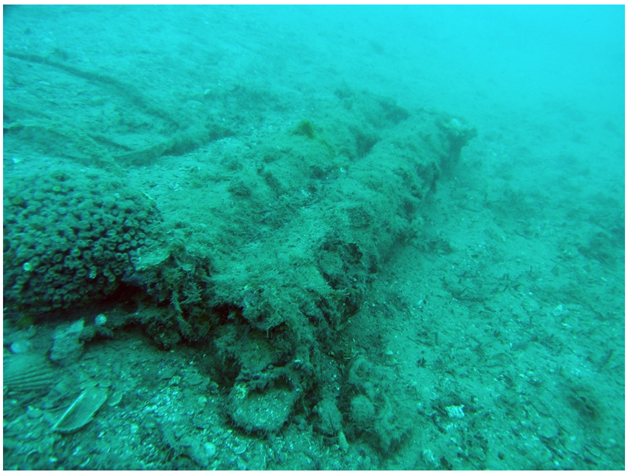

FIG. 7: Assembly of two grenades, cal. 88 mm.

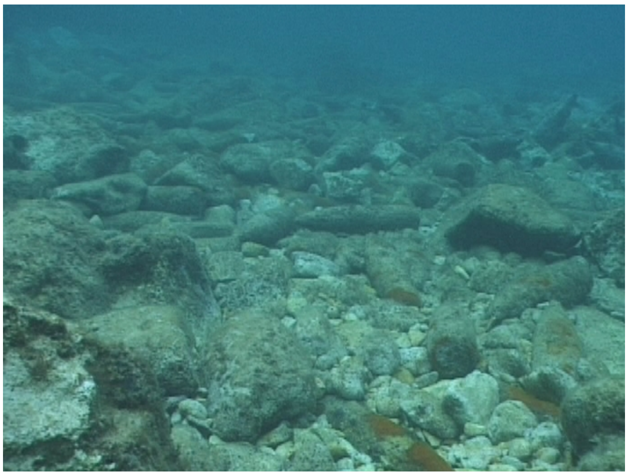

FIG. 8: Different ammunition on the sea floor.

lease didn't work or the plane is short of fuel.

Figures 5 – 8 show some of the ammunition on the bottom of the sea. Figure 9 shows the ship mine caught by fishermen.

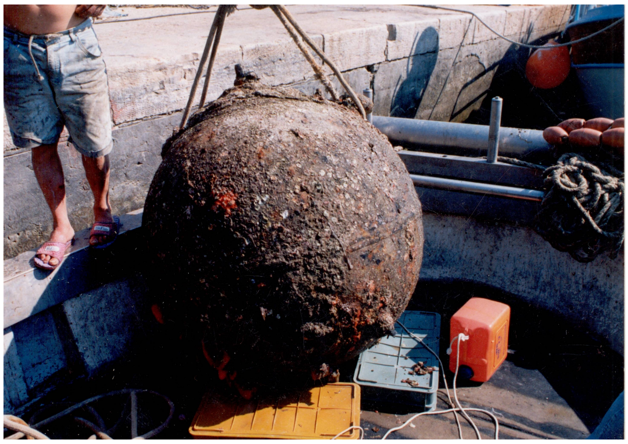

FIG. 9: Sea-mine collected by fishermen.

II. EXPERIMENTAL RESULTS

In the measurements reported here sealed tube neutron generator with the detection of associated alpha particles has been used inside a housing of an underwater vehicle.

Figure 10 shows gamma ray spectra obtained from the measurements of three different targets: explosive PETN, sediment sample and stone recovered from the sea bottom measured under the identical experimental conditions. The gamma ray spectra obtained from the measurements of the sea bottom sediments are dominated by lines of silicon, oxygen and carbon. Different sediments have different spectra, in some cases silicon lines are absent; the spectra are then characterized by the presence of calcium, oxygen and carbon lines. Figure 10 also

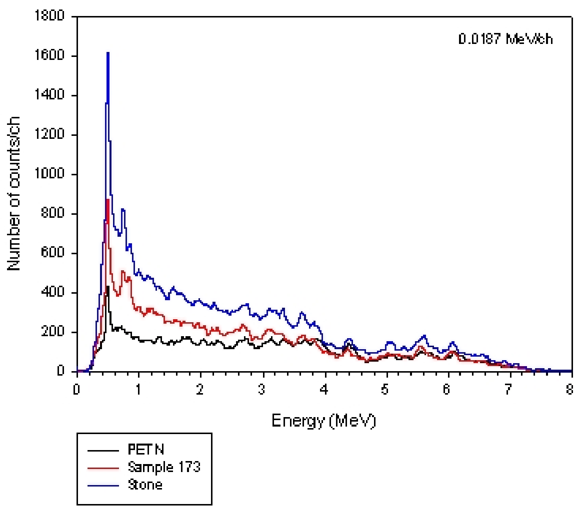

FIG. 10: Comparison of gamma ray spectra obtained from the measurements of three different targets: explosive PETN, sediment sample and stone recovered from the sea bottom measured under identical experimental conditions.

FIG. 11: The first prototype of the “Surveyor”.

shows the gamma ray spectrum obtained from the explosive PETN, chemical formula $C_5H_8N_4O_{12}$. The measured spectrum shows clearly lines of oxygen and carbon but there is no clear evidence of nitrogen line presence.

The result of this measurement shows that the presence of explosive on the sea bottom could be identified from the analysis of whole spectrum rather than the identification of individual chemical elements.

The neutron generator used by the “Surveyor” is rotated by two step motors so that different volume elements chosen by the relative position of the neutron generator and gamma ray detector could be inspected. In such a way a profile of concentrations values through the inspected volume could also be measured.

The first prototype of the underwater system “Surveyor” containing neutron generator, shielding and gamma ray detector is shown in Fig. 11 and 12. The neutron generator used by the “Surveyor” is rotated by

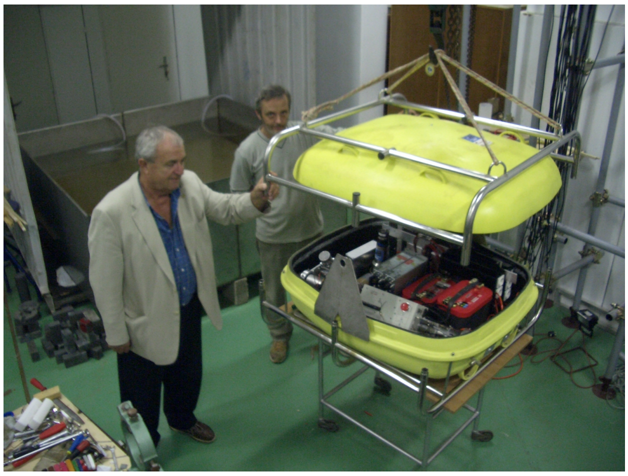

FIG. 12: Opening of the “Surveyor” for inspection of components after the measurements performed in the test chamber (in the background).

two step motors so that different volume elements chosen by the relative position of the neutron generator and gamma ray detector could be inspected. In such a way a profile of concentrations could also be measured.

Acknowledgement

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[1] Advisory Committee on Protection of the Sea (ACOPS), “Coastal Survey of Packaged Chemical and other Hazardous Items 2002/2003”, Maritime and Coastguard Agency Research Project No. 488, London, October 2003.
[2] Andrulewicz, E, “War Gases and Ammunition in the Polish Economic Zone of the Baltic Sea”, in “Sea-Dumped Chemical Weapons: Aspects, Problems and Solutions”, Ed. AV Kaffka, Kluwer Academic Publishers, Dordrecht, 1996, pp 9-15.
[3] Australian Goverment, Department of Defense, “Chemical Warfare Agent sea Dumping off Australia”, revised and Updated Edition 2003, Canberra ACT 2600.
[4] Fedorov, LA, “Pre-Convention Liquidation of Soviet Chemical Weapons” in “Sea- Dumped Chemical Weapons: Aspects, Problems and Solutions”, Ed. AV Kaffka, Kluwer Academic Publishers, Dordrecht, 1996, pp 17 – 27.
[5] HELCOM, “Report on Chemical Munitions Dumped in the Baltic Sea”, Report to the 16th Meeting of the Helsinki Commission 8-11th March 1994 from the Ad Hoc Working Group on Dumped Chemical Munitions, HELCOM CHEMU, January 1994.
[6] Hoffsommer, JC and Rosen, JM, “Analysis of Explosives in Sea Water”, Bulletin of Environmental Contamination & Toxicology, 7, No. 2/3, 1972, pp 177-181.
[7] Lotufo, GR, Farrar, JD, Innouye, LS, Bridges, TS and Ringelberg, DB, “Toxicity of Sediment-associated Nitroaromatic and Cyclonitramine Compounds to Benthic Invertebrates”, Environmental Toxicology and Chemistry, 20, 2001, pp 1762-1771.
[8] OSPAR Commission, the 2004 update on “Convention-wide Practices and Procedures in Relation to Dumped Chemical Weapons and Munitions”, 2004, ISBN 1-904426-53-0.
[9] OSPAR Commission, “Overview of Past Dumping at Sea of Chemical Weapons and Munitions in the OSPAR Maritime Area”, 2004 (Revised), ISBN 1-904426-54-9.
[10] Sea Mines & Countermeasures in the 20th Century: A Bibliography.
[11] Sea Mines & Countermeasures: A Bibliography. Mine Detection and Detectors.
[12] C.Bruschini, “Commercial Systems for the Direct Detec-

tion of Explosives" Final Report 17/2/2001, EPFL Lausanne, Switzerland

[13] V.Valkovic, IAEA Technical Meeting on Combined Devices for Humanitarian Demining and Explosives Detection, 13-17 November 2006, INFN, Padova, Italy; see **STI/Pub/1300** (2007) ISBN 978-92-0-157007-9.

[14] Vladivoj Valkovic, Davorin Sudac, Dario Matika, Robert Kollar: "An underwater system for explosive detection", SPIE Conference, Orlando 2007, Proc. paper 6540-35.

[15] B. Perot, G. Perret, A. Mariani, J.L. Ma, J.L. Szabo, E. Mercier, G. Sannie, G. Viesti, G. Nebbia, S. Pesente et al., "The EURITRACK project: development of a tagged neutron inspection system for cargo containers", Proc. SPIE, Vol. 6213 (2006) 621305.

[16] R. Monfils, "The Global Risk of marine Pollution from WWII Shipwrecks: Examples from Seven Seas", Submitted to International mOil Spill Conference, Miami, Florida, 2005.

[17] United Nations Environmental Programme, "Dumping sites of Ammunitions in mediterranean Sea", UNEP (DEPI) MED WG. 316/inf. 12 23 May 2007.

[18] Kaffka, A.V. (1996) "Sea-Dumped Chemical Weapons: Aspects, Problems and Solutions". Proceedings of the NATO Advanced Research Workshop on "Sea-Dumped Chemical Munitions", Kaliningrad, Russia, January 12-15, 1995. edited by Alexander V. Kaffka.

[19] SPREP (2003) "Regional Strategy to Address Marine Pollution from WWII Shipwrecks in the Pacific". Phase 1- Report and Preliminary Risk Assessment. CD-ROM.