THE MAIN RESULTS OF COMPILATION OF BASIC DATA OF SEAWATER POLLUTION, GEOMORPHOLOGICAL AND HYDRO-ENGINEERING PROBLEMS IN THE POTI-PORT AND ADJACENT REGIONS OF BLACK SEA COAST OF GEORGIA

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Georgian Partners of the ICME Project 2013-2015
"Integrated Coastal Monitoring of Environmental Problems in the Sea Region and the Ways of their Solution"

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This article is a brief Review of activities of the Georgian partner of the ICME Project – "Integrated Coastal Monitoring of Environmental Problems in the Sea Region and the Ways of their Solution" made in the period 2013-2015. It presents main results of compilation of basic data of seawater pollution, geomorphological and hydro-engineering problems in the Poti-Port and Anaklia regions of Black Sea coast of Georgia and on the develop of appropriate mathematical models for solution these problems

Key words: ***estuary, port, waves, coastline,water quality, submerged canyon, pollution, hydromechanics, direct and asymptotic methods***

Introduction

By the decision of the Government of Georgia, the ancient maritime gateway – city of Poti and its bordering territory should be declaredin the nearest future as a Free Trade Zone. In Anaklia, near the mouth of the Inguri River, in the near future it is planned to startthe construction of one of the largest ports not only of Georgia but also of the entire Eastern Coast of the Black Sea with an annual turnover of up to 100 million tons. A successful implementation of these international decisions directly depends on the correct assessment of hydro-engineering, geo-morphological and environmental problems which have emerged and existed since the beginning of the first half of the past century in the Poti-Port Region and and may occurin theAnakliaRegion as well.

Large-scale geo-morphological changes on the coastal line of Poty city began after 1939 when the Rioni river course was completely thrown to the north of the city. Although this event itself prevented the town from dangerous flooding processes, but, on other hand, there was an irreparable deficiency of coast generating sediments. The costal line of Poti City was catastrophically washed out by sea waves and it was reduced by hundreds of meters. On the sea shore of Poti many protection walls and engineering structures were constructed; a huge quantity of concrete blocks, broken stones and boulders were spread, but these measures were incapable to

stop the intensive process of sea shore erosion, which became even more intensive after the exploitation of the as a result of the operation of the power plant cascades of Gumati and Vartsikhe (the solid sediment of the river Rioni after the construction of the power plant cascades of Gumati and Vartsikhe reduced from 2.07 million m^3 to 1.35 million m^3 per year).

Moreover, the diversion of the Rioniriver to the north created problems for navigation because of siltation of the inlet channel of the Poti sea port caused by north-western storms and sea currents. Removal of sediments dredges is very costly and every year the port administration has to spend tens of thousands of dollars on this work.

Fig. 1.The "GOOGLE earth" pictures of *a*) Poti and *b*) Anaklia Black Sea coast regions

To restore the washed-out sea coast of Poti, in 1959, the dam with a regulator (sluice) was built across the Rioniriver, on the 7th kilometre to the north-east of Poti. Its purpose was to divide the river flow so that a part (≈ 400 m3 /s) of the river discharge would go back to the former river bed (the so-called city channel) in order to compensate for a sediment deficit (600 m3 per year). However even the discharge of 200 m3 /s produced the flooding of the town because of the city channel siltation and the deformation of the channel outlet by sea waves (which occurred during the low water period). To protect the city from floods, the channel was enclosed with dams; two water collectors and a pumping station were built. However, these measures failed to provide the required water discharge rate. That was why in the 80s of the past century, in order to reconstruct the washed-out sea shore of Poti the pulp feed-line was erected along the city channel to transport inert materials from the Rioni river basin to the sea coast. But this feed-line soon went out of order and for various reasons was not restored.

With a lapse of time, the downstream wall and the apron of the Rioni water dividing dam got essentially destroyed and the dam itself faced destruction. In 2006, it was partly rehabilitated (speaking more exactly, temporary measures were taken to rehabilitate it) according to the project prepared by the Saktskalproekti (Georgian Water Project) company. However this project was not concerned with the operation regime of the regulator and therefore with problems of restoration of the sea coast of Poti.

Thus the water dividing dam with a regulating sluice failed to meet its purpose to deliver sediments to the sea coast.

This brief historical information clearly shows how topical it is to carry out scientific investigations of hydro-engineering and environmental problems existing in the Poti region and to

propose such engineering measures that would facilitate to a maximal extent the restoration of the Poti coastline and protect the port of Poti from the inflow of river sediments.

The main purpose of the present project was to work out such scientifically justified engineering measures that can be used when solving the above-mentioned problems by the proposed new analytical and numerical methods of the applied theory of wave motion and sediment transport.

Objects of Research

In the ICME project the following parts ofpoti and anaklia black sea regions were investigated:

1. **The coastline of the city of Poti ;**
2. **The entrance channel of the Poti port;**
3. **The water dividing dam on the river Rioni;**
4. **The bed and outlet of the city channel;**
5. **Sea resort of Anaklia coastline**

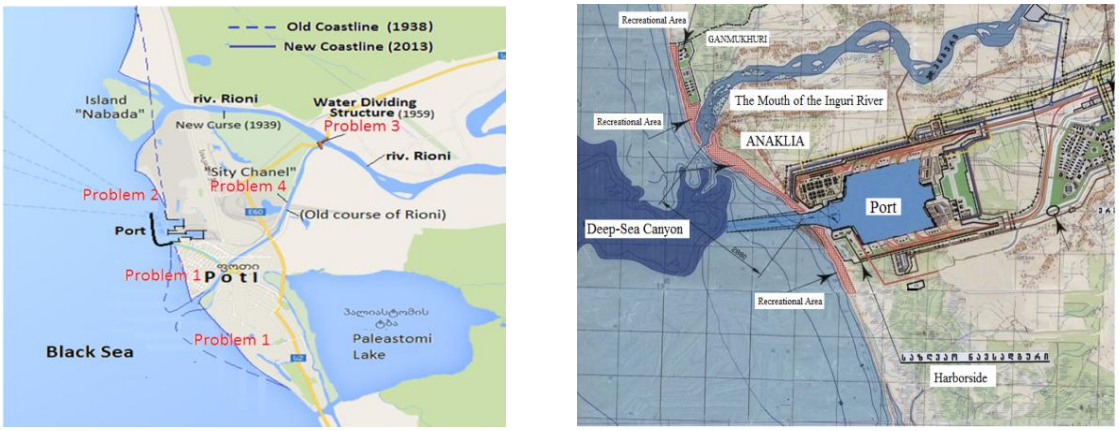


Fig. 2. Situational Maps for Hydro-Engineering and Environmental problems of Poti and Anaklia Black Sea Regions of Georgia

Results of the Fulfillment of the Tasks of Group Activities Ga1

a) Strategy of sampling sea and river water for their chemical analysis, together with representatives of the Georgiansabcontractor, LTD "TBILTSCALGEO", as well with Armenianpartners. This plan was implemented by the several joint expeditions in the mouths of rivers and in coastal areas of the main Black Sea towns of Western Georgia;

b) These expedition also identified the causes of erosion of coasts of the city of Poti and Anaklia resort and identified the causes of the destruction of the downstream of water-divided dam on the river Rioni near Poti;

c) For the above-listed objects in the Poti region and Anaklia the following steps were taken: the relevant hydrological and meteorological observations data we collected and processed; topographic and bathymetric maps and other materials were prepared; expeditions were organized to carry out field observations of the investigated objects; the obtained data on geomorphological changes were processed and classified.

d) The current projects on the extensive development of the Poti sea port and construction of the port in Anaklia (near the mouth of river Inguri) were studied;

e) The factors which caused the destruction of the downstream wall of the Rioni flow dividing structure were identified;

f) For the purpose of sea coast growth, possibilities of the pulp feed-line rehabilitation and construction of a sediment-retaining barrier along the underwater canyon located near the southern pier of the Poti port were considered;

g) Engineering measures for preventing the Poti port from siltation were worked out taking into account variants of the reconstruction and extensive development of the Poti port;

h) Engineering decisions were proposed for cleaning the city channel bed and increasing its capacity

Results of the study of the concentration of pollutant missions by industrial enterprises of the city of Poti

The flows of wastewaters into the sea from the industrial enterprises of Poti have the following physic-chemical characteristics:

a) The Milling Plant

1. **Water temperature 18-20^{o} C ;**
2. **Transparency 15-20 cm – not permissible;**
3. **Suspended solids 1500-1000 mg /l - not permissible;**
4. **PH – 6.5;**
5. **The total hardness of water 2.5;**
6. **Solids residue 600 mg / l - not permissible;**
7. **Ca2+ -15; Mg2+ - 4; Cl - 60; SO 42 - - 100 ; Fe general - 2 ;**
8. **BOD - 250; COD - 600 - not permissible;**
9. **P2O5 – 3,2;**
10. **Nitrogen - 3,0.**

b) The Oil Refinery Plant

1. **Suspended solids 25 mg / l;**
2. **Petroleum products – 25 mg /l - not permissible;**
3. **PH – 7 - 8,5;**
4. **Hardness 20;**
5. **Solids residue to 2000 mg/ l- not permissible;**
6. **SO_4^{2-} - 500 - not permissible;**
7. **Cl – 300;**
8. **BOD - 25- not permissible.**

c) The Shipyard

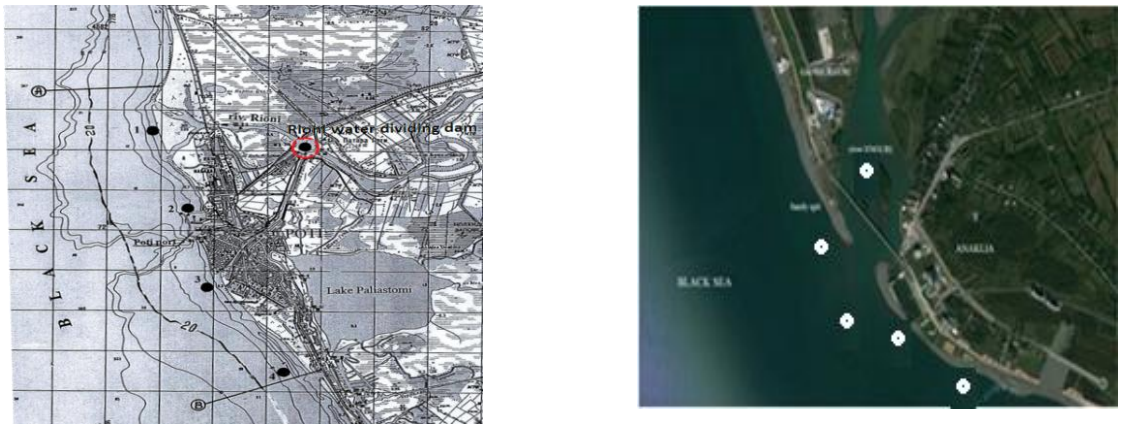
1. **Suspended solids 20 mg /l;**
2. **PH – 7 - 8;**
3. **The total hardness of water 2.5;**
4. **Water temperature 25 - 60° C ;**
5. **Solids residue to 1000 mg /l- not permissible;**
6. **Cl – 200;**
7. **SO_4^{2-} - 400;**
8. **Fe general - 2 - not permissible;**
9. **Oxidation -20 mg / l - not permissible;**
10. **BOD - not normalized - not permissible.**

Results of the study of water quality in Poti and the coastal areas of its asjacent regions

Water sampling for hydro-chemical, biogenic and bacteriological analyses were continued and 100-120 water samples were taken for the period 2013-2015. The water samples were analyzed at the Laboratory Test Centre in Poti and TbilTskalGeo hydro-chemical laboratory in Tbilisi. 2500 tests were run totally on 18 pollution ingredients. Obviously, such a number of tests is quite sufficient for statistic processing of the data. Average results of hydro-chemical, biogenic and bacteriologic analyses for each accounting year are given in Tables 1- 5 (See. Appendix 1).

Water samples were taken from selected points, includingthe points at the last section of watershed dam of the river Rioniand Anaklia region. Their locations are given below in the presented map and in the " Google earth"picture of Anaklia (see Figure 3. a, b).

Statistic processing of the test data includes the extension of the observation line by comparing them to the analogous units and by analyzing them. Besides, the correlation will be identified and proper regression equations will be prepared. Just for illustration purposes, we would like to present some preliminary results of the correlation analyses, which are provided in the report.



a) Poti Region **b) Anaklia Region**

Fig. 3.

Preliminary rough calculations showed that there is clear and obvious correlation:

a) with the water discharge mineralization – correlation factor $r \approx 0.93$**,the regression equations are:**

$$C - 218 = -8.4(Q - 5.65),$$

$$Q - 5.65 = -0.1(C - 218.4),$$

Here C is mineralization of the river Rioni stream, Q – discharge;

b) between the coli-index and the water discharge - correlation factor $r \approx 0.63$**, the regression equations are:**

$$\begin{cases} C - 48.1 = 3.51(Q - 16.2) \\ Q - 16.2 = 0.11(C - 48.1) \end{cases}$$

Here C is the coli- index in the stream;

c) between nitrates and discharges: $r \approx 0.34$**, the regression equations are:**

$$\begin{cases} C - 1.31 = 0.058(Q - 20.1) \\ Q - 20.1 = 2.0(C - 1.3) \end{cases}$$

Here C is the nitrate concentration;

d) between coli-index and nitrates. $r \approx 0.89$**, theregression equations are:**

$$\begin{cases} C_{ni} - 2.5 = 0.023(C_k - 128.1) \\ C_k - 128.1 = 35.0(C_{ni} - 2.5) \end{cases}$$

The facilities and enterprises pollutingPoti were identified in parallel and types and quantity of their production were determined. With these data and calculation method elaborated at TbilTskalGeo, it is possible to define the concentrations of polluting substances for points of the Black Sea waters.

Some information and materials about the tests of bottom sediments for the sea waters to be studied were obtained. It is very important to identify secondary pollution coming from the bottom sediments as such processes have more and more frequent and growing nature over the time.

Calculation relations for identifying the withdrawal of polluting substances by the rivers with diffusive mechanism within the solid sediment sedimentation zone are given in [4].

Points of sampling in the Poti and Anaklia Regions

All the expeditions for sampling seawater and their physico-chemical analysis included the following personnel of Georgian LTD "TBILTSCALGEO": TS.Khozrevanidze; Z. Askurava (LTD Supervisor); E.Khatiashvili (Scientific Supervisor); Z.Bagashvili (Work Supervisor); E.Chanturishvili (V.Svianadze (See below the protocol on the results of the 3rd Stage of the expedition in February-August 2014 drawn up in Poti) from the Georgian part. From Armenianpart, the representatives of the Yerevan State University of Architecture and Construction A.Sarukhanyan and P. Baljyan participated as observers in the these sampling and laboratory analyses.

Mathematical models of wave propagation, pollution and sediment migration in the estuarine and coastal waters of non-tidal seas

- **The Mathematical Models pursued the aim to solve the applied problems of coastal hydrodynamics and hydraulic engineering. These theoretical studies are also of fundamental nature. In particular, the following problems have been solved in the project:**
- **A new approach to solving the problem of wave propagation in the flow of variable depth. In particular, by the correct linearization of shallow water equations we obtained a number of unique results, one of which is in particular as follows: the wave propagation against the flow is blocked by a stream with Froude number Fr>2/3, but not with Fr> 1, as previously thought [1,5];**
- **A new approach to the practical solution of the wave refraction problem and the calculation of a three-dimensional velocity field on coastal slopes of arbitrary steepness [2];**
- **The hydrodynamic stability of streams in gravity-flow cylindrical conduits [3];**
- **The influence of surface waves on the distribution of contaminants in coastal areas [4];**
- **For the case of propagation of longitudinal waves superposed on flows in channels of trapezoidal cross-section, relations have been derived for predicting deformation of the channel**

sides and also for a choice of dimensions of channel reinforcement elements (rock filling and facing slabs) [5];

- **The hydraulic calculation method has been developed for a sea bottom sewage spillway [6].**

Results of laboratory studies of the action of waves on the pollution spread

This activity should have been conducted in Turkeyat KTU lab. However, for Turkish, Georgian and Armenian parties, it turned out to be more convenient to carry out experiments on the Action of Waves on the Pollution Spread in one of the laboratories in Tbilisi.

These experiments have been largely qualitative in nature, and their main goal was to identify the effect of waves on the distribution of impurities entering the sea from both the deep sewer outlet and from the river inflow.

The experiments have shown that short waves contribute toan increase of the pollutant concentration near the coast, while long waves to the contrary diminish it by carrying pollutants into the sea depth. Along with this, vertical and horizontal jets of impurities get strongly bent under the action of waves. It would be highly desirable to continue experimental and theoretical research in this direction.

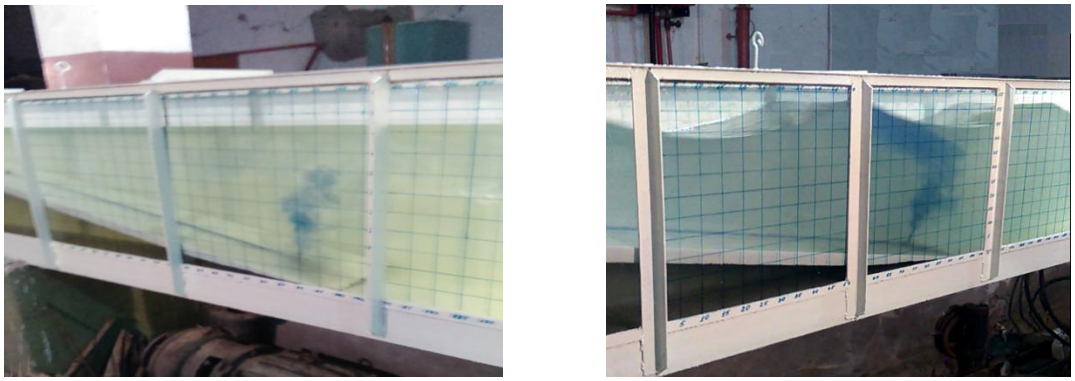


Fig. 4. Photos of laboratory study effects of waves on contaminants arriving from the deep sewage outlet

The experimental researchfor the river tributaries has been carried out in the pool having the following dimensions: Length=13m., width=3m., depth=0.65m. The pool is equipped witha generator of variable wave frequency (Figure 4), a pumping system with a small retaining tank equipped with a discharge meter and the connecting pipe line for water supply and discharge.

Fig. 5. Photos of laboratory studies of wave effects on pollutants brought into the sea by the river inflow

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2. **Gagoshidze Sh. To the Calculation of Waves Refraction at the Shore Slope Having Arbitrary Steepness. Geophysical Research Abstracts// EGU General Assembly. Vienna. Austria. 27 April– 02 May 2014.**
3. **Gagoshidze Sh. On the Stability of Wave Disturbances in Non-Pressure Round-Cylindrical Channel. Geophysical Research Abstracts// EGU General Assembly 2015. Venna. Austria. 12-27 April 2015.**
4. **Gagoshidze Sh., E.Khatiashvili, Influence of Surface Waves on the Distribution of Contaminants in the Sea Coastal Areas//Energy. 2015. №1(73). Tbilisi.**
5. **Gagoshidze Sh., Lordkipanidze M. Longitudinal Waves in Channels and their Action on Bank Slopes//Energy. 2015. №1(73).**
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Note: The full texts of these abstracts and articles listed below in this journal. They are listedalso on the link

http://www.researchgate.net/profile/Shalva_Gagoshidze2/publications

APPENDIX 1

Tables of average results of hydro-chemical, biogenic and bacteriologic analyses for each accounting year

1st Stage February-August 2013

Table 1

#	pH	БПК$_5$	Dissol-ved Oxygen	Basic Ions							Biogenic Elements				Micro Elements		Oil product	$\mathcal{E}$ - Coli
				HCO_3^- Mg/l	Cl^- Mg/l	SO_4^{2-} Mg/l	Ca^{2+} Mg/l	Mg^{2+} Mg/l	Na^+ Mg/l	K^+ Mg/l	NH_4^+ Mg/l	NO_2^- Mg/l	NO_3^- Mg/l	PO_4^{3-} Mg/l	Fe Mg/l	Mn Mkg/l		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
MaltakvaKaparcha merging the sea	8.1	2.4	8.4	59.2	7000	700	240	680	5100	200	-	-	0.1	1.5	<0.05	-	0.2	5214
Poti. Sea near lighthouse (2 points)	8.3	3.7	7.12	91	7750	1100	230	590	4900	190	-	-	0.1	2.0	<0.05	-	0.8	4018
Poti. Sea near Port (2 points)	8.2	3.6	6.7	91.5	8500	1100	230	620	5100	200	-	-	0.1	2.0	<0.05	-	0.9	6890
RioniNabada (2 points)	8.0	3.2	7.6	80.7	8250	900	240	610	5000	205	trace	-	0.1	1.5	<0.05	-	0.9	7312
Rioni watershed	8.0	2.45	7.9	170.8	120.9	14.4	32.8	5.9	205.9	19.5	-	-	1.0	1.1	0.3	5.1	0.1	4320

2nd Stage August-January 2014

Table 2

#	pH	БПК$_5$	Dissol-ved Oxygen	Basic Ions							Biogenic Elements				Micro Elements		Oil product	$\mathcal{E}$ - Coli
				HCO_3^- Mg/l	Cl^- Mg/l	SO_4^{2-} Mg/l	Ca^{2+} Mg/l	Mg^{2+} Mg/l	Na^+ Mg/l	K^+ Mg/l	NH_4^+ Mg/l	NO_2^- Mg/l	NO_3^- Mg/l	PO_4^{3-} Mg/l	Fe Mg/l	Mn Mkg/l		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
MaltakvaKaparcha merging the sea	8.0	2.2	8.0	55	75	650	230	550	4500	200	-	-	0.1	1.5	<0.05	-	0.1	5718
Poti. Sea near lighthouse (2 points)	8.1	2.5	7.6	80.0	7700	700	230	570	4500	180	-	-	0.1	1.5	<0.05	-	0.4	7049
Poti. Sea near Port (2 points)	8.2	3.1	7.6	80.2	8000	820	230	590	4900	200	-	-	0.1	1.5	<0.05	-	0.5	6912
RioniNabada (2 points)	8.2	3.4	7.4	87	8200	910	230	600	5000	200	trace	trace	0.5	2.0	<0.05	-	0.5	7152
Rioni watershed	8.0	2.45	7.9	170.8	120.9	14.4	32.8	5.9	205.9	19.5	-	-	1.0	1.1	0.3	5.1	0.1	4320

3rd Stage February-August 2014

Table 3

#	pH	БПК$_5$	Dissol-ved Oxygen	Basic Ions							Biogenic Elements				Micro Elements		Oil pro-duct	$\mathcal{E}$ - Coli
				HCO_3^- Mg/l	Cl^- Mg/l	SO_4^{2-} Mg/l	Ca^{2+} Mg/l	Mg^{2+} Mg/l	Na^+ Mg/l	K^+ Mg/l	NH_4^+ Mg/l	NO_2^- Mg/l	NO_3^- Mg/l	PO_4^{3-} Mg/l	Fe Mg/l	Mn Mkg/l		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
MaltakvaKaparch a merging the sea	8.5	2.6	8.8	62.2	7350	735	252	714	5355	220	-	-	0.1	1.2	<0.05	-	0.2	5736
Poti. Sea near lighthouse (2 points)	8.7	3.8	7.6	100.1	8525	1210	253	640	5390	200	-	-	0.1	2.2	<0.05	-	0.9	4420
Poti. Sea near Port (2 points)	8.6	3.7	7.4	100.6	8925	1155	253	680	5610	220	-	-	0.1	2.0	<0.05	-	1.0	7120
RioniNabada (2 points)	8.0	3.5	7.6	90.2	8520	990	264	670	5500	225	trace	-	0.1	1.5	<0.05	-	0.8	7530
Rioni watershed	8.3	2.65	8.1	183.0	133	16.0	36	6.5	226	22	-	-	1.1	1.2	0.3	5.6	0.2	4560

4th Stage August-January 2014

Table 4

#	pH	БПК$_5$	Dissol-ved Oxygen	*Basic Ions*							Biogenic Elements				Micro Elements		Oil pro-duct	$\mathcal{E}$ -Coli
				HCO_3^- Mg/l	*Cl^- Mg/l*	*SO_4^{2-} Mg/l*	*Ca^{2+} Mg/l*	*Mg^{2+} Mg/l*	*Na^+ Mg/l*	*K^+ Mg/l*	NH_4^+ Mg/l	NO_2^- Mg/l	NO_3^- Mg/l	PO_4^{3-} Mg/l	Fe Mg/l	Mn Mkg/l		
	1	2	3	*4*	*5*	*6*	*7*	*8*	*9*	*10*	11	12	13	14	15	16	17	18
MaltakvaKaparch a merging the sea	7.8	2.1	7.8	*53*	*73.5*	*635*	*225*	*550*	*4500*	*200*	-	trace	0.1	1.5	<0.05	-	0.1	5718
Poti. Sea near lighthouse (2 points)	8.1	2.5	7.6	*80.0*	*7700*	*700*	*227*	*560*	*4410*	*175*	trace	-	0.1	1.3	<0.05	-	0.3	6910
Poti. Sea near Port (2 points)	8.0	2.9	7.4	*76.8*	*7840*	*805*	*225*	*575*	*5200*	*185*	-	-	0.1	1.2	<0.05	-	0.4	6720
RioniNabada (2 points)	8.1	3.3	7.2	*85*	*8040*	*895*	*220*	*580*	*4900*	*190*	trace	trace	0.5	2.0	<0.05	-	0.5	7152
Rioni watershed	8.0	2.45	7.9	*170.8*	*120.9*	*14.4*	*30.1*	*5.9*	*200*	*18*	trace	-	1.2	1.0	0.5	5.3	0.2	4200

5rd Stage February-August 2015 (Anaklia)

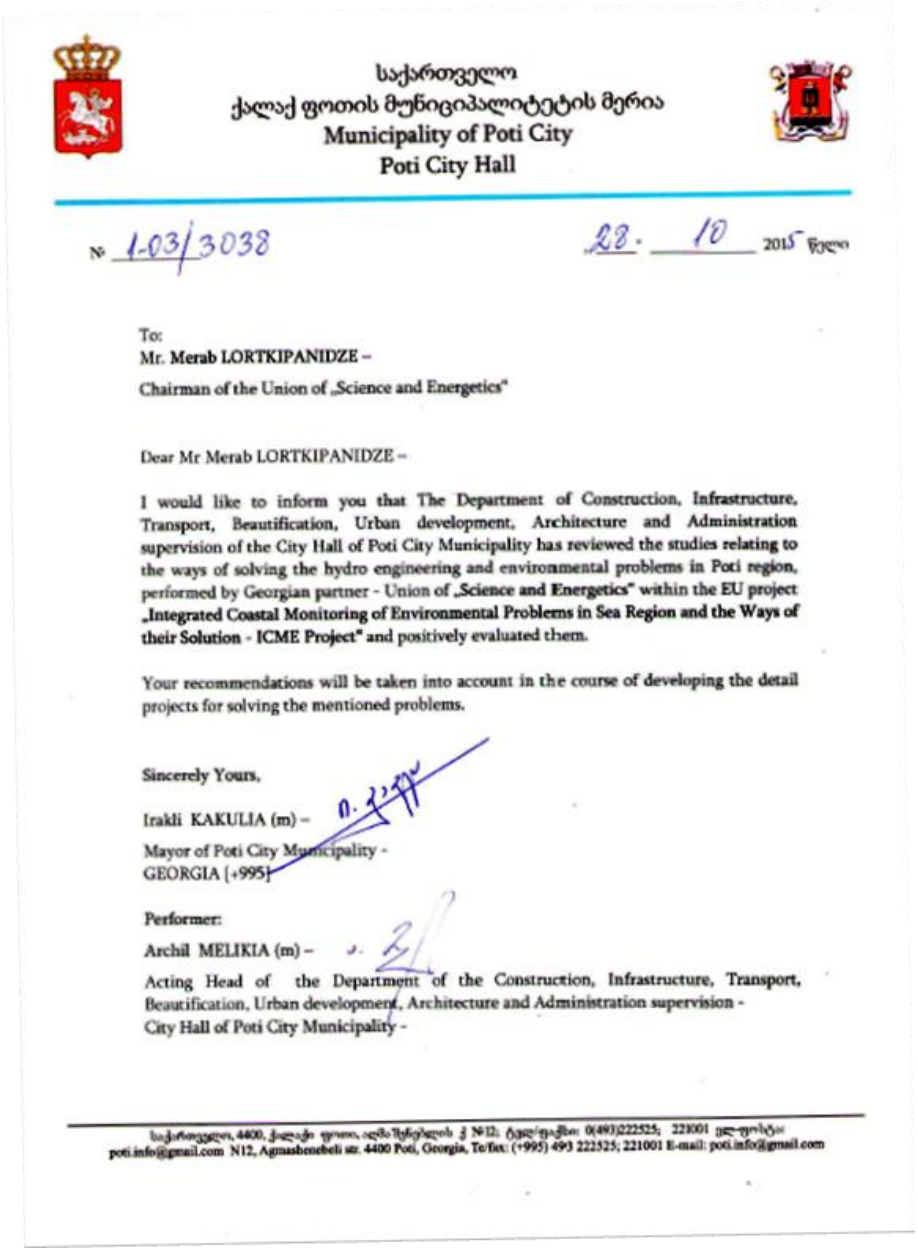
Table 5

#	pH	БПК$_5$	Dissolved Oxygen	Basic Ions							Biogenic Elements				Micro Elements		Oil product	$\mathcal{E}$-Coli
				HCO_3^- Mg/l	Cl^- Mg/l	SO_4^{2-} Mg/l	Ca^{2+} Mg/l	Mg^{2+} Mg/l	Na^+ Mg/l	K^+ Mg/l	NH_4^+ Mg/l	NO_2^- Mg/l	NO_3^- Mg/l	PO_4^{3-} Mg/l	Fe Mg/l	Mn Mkg/l		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Ingurimerging the sea (1 point)	8.8	3.7	8.9	100.2	8405	735	282	714	5290	220	-	-	0.1	2.7	<0.05	-	0.08	5536
Anaklia. Sea water near coastline (2 points)	8.3	3.4	7.8	90.5	8525	1210	245	640	5330	200	-	-	0.1	2.1	<0.05	-	0.5	4020
Anaklia. Deep-Sea Canyon near river mouth (1 point)	7.6	2.5	7.0	88.6	8025	1155	233	680	5510	205	-	-	0.1	1.5	<0.05	-	0.8	3712
Ganmukhuri, Sea water near coastline (1 point)	7.7	2.8	7.0	90.2	7820	990	233	670	5500	215	-	-	0.1	1.9	<0.05	-	0.8	3753

APPENDIX 2

The letter of the Municipal Authorities of Poti

with a positive appraisal of the studies performed by the Georgian partner - Union of „Science and Energetics" in the framework of the EU project „Integrated Coastal Monitoring of Environmental Problems in the Sea Region and the Ways of their Solution - ICME Project".



საქართველო
ქალაქ ფოთის მუნიციპალიტეტის მერია
Municipality of Poti City
Poti City Hall

№ 1-03/3038 28. 10 2015 წელი

To:
Mr. **Merab LORTKIPANIDZE** –
Chairman of the Union of „Science and Energetics"

Dear Mr Merab LORTKIPANIDZE –

I would like to inform you that The Department of Construction, Infrastructure, Transport, Beautification, Urban development, Architecture and Administration supervision of the City Hall of Poti City Municipality has reviewed the studies relating to the ways of solving the hydro engineering and environmental problems in Poti region, performed by Georgian partner - Union of **„Science and Energetics"** within the EU project **„Integrated Coastal Monitoring of Environmental Problems in Sea Region and the Ways of their Solution - ICME Project"** and positively evaluated them.

Your recommendations will be taken into account in the course of developing the detail projects for solving the mentioned problems.

Sincerely Yours,

Irakli KAKULIA (m) –
Mayor of Poti City Municipality -
GEORGIA [+995]

Performer:
Archil MELIKIA (m) –
Acting Head of the Department of the Construction, Infrastructure, Transport, Beautification, Urban development, Architecture and Administration supervision -
City Hall of Poti City Municipality -

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