Clean Up Georgia – Raising of Public Awareness and Involvement in Solid Waste Management Improvement (Phase II)

NUGZAR BUACHIDZE

ASSESSMENT OF THE IMPACT OF UNCONTROLLED LANDFILL SITES IN GEORGIA ON ECOSYSTEMS OF THE SURROUNDING AREAS

Tbilisi, 2015

Within the framework of the project "Raising of Public Awareness and Involvement in Solid Waste Management Improvement" (Phase II) financed by the Swedish Government, the field works were carried out in Georgia with participation of the Georgian Society of Nature Explorers "Orchis" Working Group. The purpose of the works was to assess the role of uncontrolled landfill sites in the pollution of the surrounding areas. For this end, samples (soil, water) from the chosen research territories were sent to several leading laboratories for hydrochemical and microbiological analyses. At the same time, physicochemical properties of rivers and wastewaters were defined in the field.

In the present work, we assess pollution levels in the surrounding areas of uncontrolled landfill sites and various polluting components. In addition, we carried out a comparative analysis of numerous sites located in Eastern Georgia, Western Georgia and on the outskirts of Tbilisi, which helped us assess the hottest spots and develop appropriate recommendations. Based on the results, the conclusion has been made about the current harmful impact of these sites on human health.

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ASSESSMENT OF THE IMPACT OF UNCONTROLLED LANDFILL SITES IN GEORGIA ON ECOSYSTEMS OF THE SURROUNDING AREAS

It is well known that there are numerous uncontrolled landfill sites in different regions of our country. They are often located near settled areas and not seldom, near pastures or the gorges, where small rivers flow. Very often, it is impossible to transport waste from these sites for final disposal or to clean up the territory. As a result, uncontrolled landfills remain there for years becoming one of the sources of pollution of the surrounding areas with different types of waste. Accordingly, the sanitary state of these areas significantly deteriorates. It should be necessarily mentioned that this problem is of particular significance in our country and its resolution is very important due to the fact that, among other things, hazardous wastes find their way into these illegal landfill sites, which might cause numerous health problems in local population in future. In order to assess the level of impact of landfill sites uncontrolled by the state on the pollution of the surrounding areas, the Georgian Society of Nature Explorers "Orchis" Working Group carried out relevant fieldwork and research on the territories of Georgia, which were to be studied, within the framework of the project "Clean Up Georgia".

In accordance with the project plan, the working group chose illegal household waste landfill sites existing at the time and took samples (water, soil) for analysis from the surrounding areas in the field. Hydrochemical and microbiological analyses of the collected samples were carried out in compliance with the relevant methodologies by two leading laboratories in Georgia – Scientific Research Firm GAMMA Ltd (SST ISO/IEC 17025:2010) and the Laboratory of Monitoring Department of National Environmental Agency SST ISO/IEC 17025:2010). In all cases, physicochemical properties of surface water were analyzed (Fig. 1–4) in the field (i.e. at the sampling location).

Fig. 1. Akhaltsikhe (Kvabliani), the Potskhovi River

Fig. 2. Gully water in Ikalto village

Fig. 3. Gardabani Region, Kumisi village

Fig. 4. Guria

By using proven modern methodology and techniques (ISO methods), the laboratories have assessed the pollutants in the samples collected, which due to the direct impact of these types of landfill sites on the surrounding areas, are often the main polluters of environments and ecosystems. The analyses have assessed some principle ions, several forms of biogenic elements (NO_2^-, NO_3^-, NH_4^+, PO_4^{3-}), and heavy metals (Cu, Zn, Pb, Cd). In parallel with the abovementioned procedures, microbiological analyses (total coliforms, Faecal streptococci, and E. coli) of the pilot samples were performed, while at the sampling time, physicochemical properties of water were analyzed (pH, temperature, electrical conductivity, dissolved oxygen, and salinity) using a portable device in the field. Accordingly, the objects of our research were comprehensively studied in order to collect not only hydrochemical but physicochemical and microbiological data as well.

During the assessment of different types of ingredients for research purposes, the following methods and/or equipment (Fig. 5–8) were used:

1. Ion-selective chromatograph ICS-1000 (ISO 10304-1:2007)
2. Spectrophotometer SPECORD 205 (ISO 7150-1:2010)
3. Membrane filtration (ISO 9308-1; ISO 7899-2)
4. Plasma emission spectrometer ICP-MS
5. Portable field device

Fig. 5. Plasma emission spectrometer – ICP-MS

Fig. 6. Ion-selective chromatograph – ICS-1000

Fig. 7. Portable field device

Fig. 8. Spectrophotometer SPECORD 205

From November 1, 2013 to date, we have performed about 1000 microbiological and chemical analyses of the samples collected and assessed about 20 polluting ingredients in them. During this period, we have visited all main regions of Eastern and Western Georgia as well as the outskirts of Tbilisi. The results are shown in Table 63 and Graph 72.

For each sampling location, we have included the following physical and geographical features: altitude, coordinates, approximate area of the landfill (coordinate system WGS-84.UTM), meteorological conditions, etc. The abovementioned measurements were performed using the portable GPC device. Subsequently, the working group prepared an interactive map featuring all research locations as well as the features listed above. The online version of the map can be accessed via Google files (see Fig. 9–10).

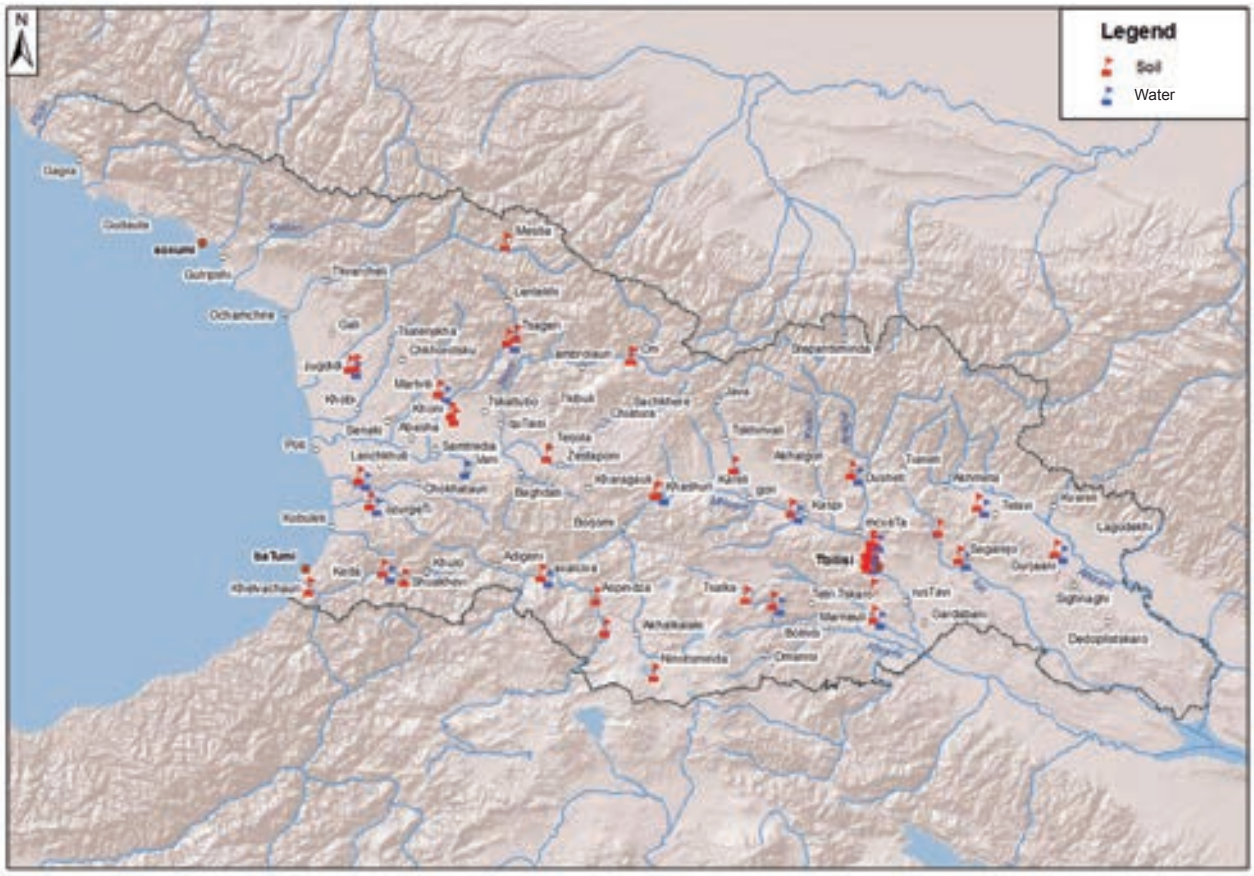


Fig. 9. Interactive map of Georgia

Fig. 10. Online version of the interactive map

EASTERN GEORGIA

Kakheti Region

In Kakheti Region, we performed hydrochemical, physicochemical, and microbiological analyses of the soil and water samples collected from the surrounding areas of the illegal landfill sites in Sagarejo, Gurjaani, and Telavi (Ikalto village). The results are shown in Tables 1–7 and Graphs 1–4.

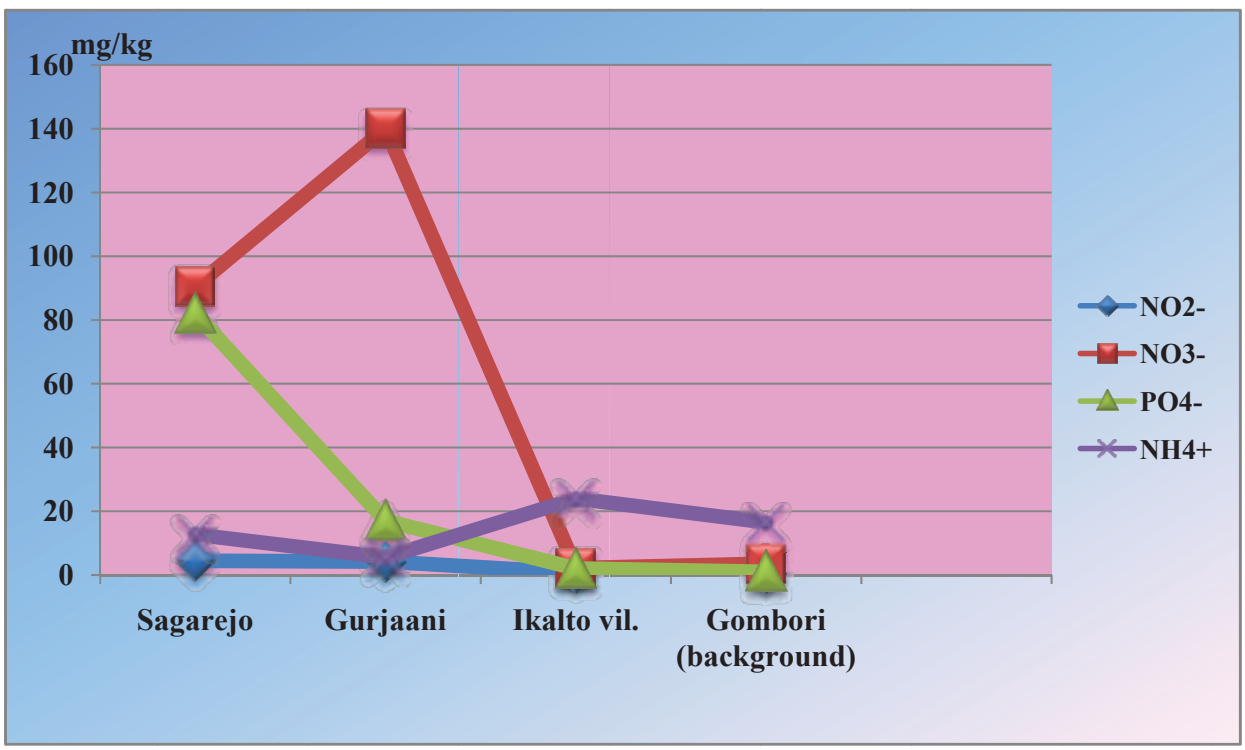
Table 1. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Kakheti Region

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	pH	HCO_3^- mg/kg	NO_2^- mgN/kg	NO_3^- mgN/kg	PO_4^{3-} mg/kg	NH_4^+ mgN/kg	SO_4^{2-} mg/kg
Sagarejo, Tskarostavi village	01.11.2013	524120 4620201	813	7.03	12.32	**4.45**	**90.5**	**82.0**	12.7	246
Gurjaani, irrigation canal (3 km from the city)	21.11.2013	568940 4623145	303	7.12	1269	**4.2**	**140**	**17.0**	5.5	1210
Telavi, Ikalto village (200 m from the settlement)	06.12.2013	532596 4644794	589	7.22	1245	0.7	2.1	2. 0	24	6
Gombori, 1200 m.a.s.l (background)	06.12.2013	513908 4634711	1200	7.02	383.0	0.1	3.5	1.0	16.5	40

In order to correctly assess the role and significance of landfill sites in the pollution process of the surrounding areas, we selected several research locations as backgrounds and compared the results obtained from the remaining locations to them. In some cases, we compared our findings to the MAC (Maximum Allowable Concentration) value of a defined component or to such values as Estimated Allowable Concentration (EAC). As shown in the Table 1, for this purpose, we chose the area (Gombori) in Kakheti Region, located at the altitude of 1200 m.a.s.l., where there is not any type of landfill nearby, which means that the location is relatively ecologically clean.

To begin with, it should be noted that all four soil samples from Kakheti Region are in the neutral region of the pH scale. From the data obtained, it becomes clear that the concentration of some components in the samples collected from the surrounding areas of landfill sites is relatively higher than in the background. For example, in the samples collected in Sagarejo and Gurjaani, the NO_2^- concentration is 40 times higher than the background value and 7 times higher in the samples collected in Telavi. The NO_3^- concentration in the sample collected in Gurjaani is 40 times higher than the background value and 26

times higher in the sample collected in Sagarejo. In the samples collected in Ikalto village, the PO_4^{3-} concentration is 2 times higher than in the background, in the samples collected in Gurjaani – 17 times higher, while in the samples collected in Sagarejo – 82 times higher. Accordingly, the highest degree of pollution with biogenic elements in Kakheti Region is in the surrounding areas of the landfill sites in Sagarejo and Gurjaani. It should also be noted that Gombori was not overloaded with the latter elements and respectively, in this specific case, was rightly chosen as a background (Table 1). It should be mentioned that this is even more evident in Graph 1.



Graph. 1. The biogenic element concentration in the soil samples collected in Kakheti Region

Table 2 shows the results of microbiological analysis of the soil samples, while in Table 3, the samples are assessed.

Table 2. The results of microbiological analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Kakheti Region

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Total coliform titer	E. coli titer
Sagarejo, Tskarostavi village	01.11.2013	524120 4620201	813	**0.0001**	**0.0001**

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Total coliform titer	E. coli titer
Gurjaani, irrigation canal (3 km from the city)	21.11.2013	568940 4623145	303	0.001	0.001
Telavi, Ikalto village (200 m from the settlement)	06.12.2013	532596 4644794	589	0.01	0.01
Gombori, 1200 m.a.s.l (background)	06.12.2013	513908 4634711	1200	0.1	0.1

Table 3. The scheme of the sanitary state assessment of soil pollution with microbiological elements

Category of soil	Total coliform titer	E. coli titer
Not polluted (clean)	1.0 and higher	1.0 and higher
Polluted	0.9–0.01	0.9–0.01
Heavily polluted	0.009 and lower	0.009 and lower

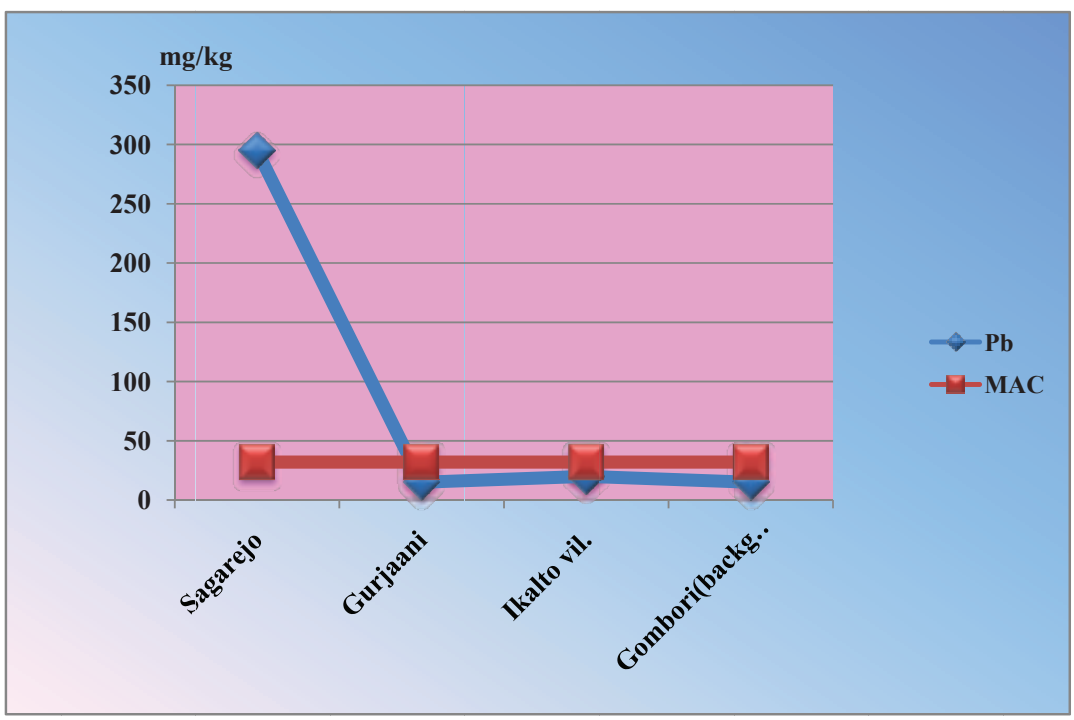
Based on the data shown in Tables 2 and 3, it can be said that all soil samples collected from three research locations in Kakheti Region—the surrounding areas of the landfill sites in Sagarejo and Gurjaani—are heavily polluted with total coliforms (a common indicator of intestinal bacteria), and E. coli (one of the active forms of intestinal bacteria), while the territory of Ikalto village can be categorized as polluted. Based on the data obtained, we can conclude that from eco-chemical and eco-biological viewpoints, the abovementioned areas are under rather intensive anthropogenic impact because of the landfill sites and accordingly, it can create a hazard to both human and domestic animal health.

As already mentioned, the heavy metal (Cu, Zn, Pb, Cd) concentration was assessed in the samples collected. The results are shown in Table 4 and Graphs 2–3.

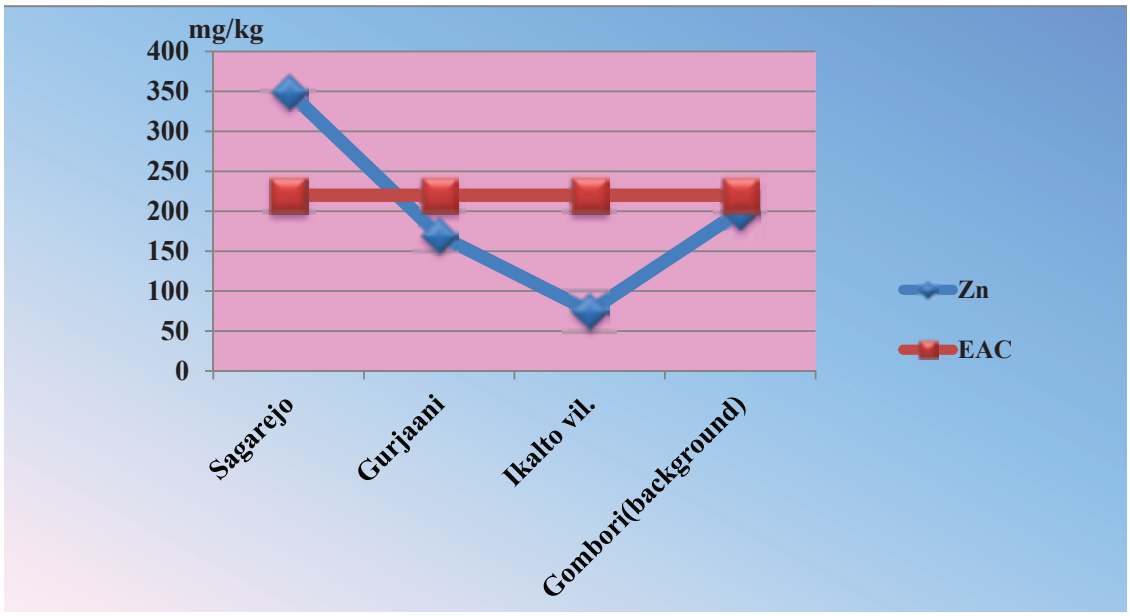
Table 4. The heavy metal (Cu, Zn, Pb, Cd) concentration in the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Kakheti Region

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Cu, ppm	Zn, ppm	Pb, ppm	Cd, ppm
Sagarejo, Tskarostavi village	01.11.2013	524120 4620201	813	65	350	295	<2.5
Gurjaani, irrigation canal (3 km from the city)	21.11.2013	568940 4623145	303	70	170	15	<2.5

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Cu, ppm	Zn, ppm	Pb, ppm	Cd, ppm
Telavi, Ikalto village (200 m from the settlement)	06.12.2013	532596 4644794	589	20	75	20	<2.5
Gombori, 1200 m.a.s.l (background)	06.12.2013	513908 4634711	1200	150	200	15	<2.5
Maximum Allowable Concentration (MAC)						32	
Estimated Allowable Concentration (EAC)				132	220	130	2.0



Graph 2. The lead concentration in the soil samples collected in Kakheti Region



Graph 3. The zinc concentration in the soil samples collected in Kakheti Region

It can be clearly observed that the total heavy metal concentration in the soil samples is rather high. Namely, in the soil samples collected from the surrounding areas of Sagarejo, the lead concentration is 9 times higher than the MAC, and 2 times higher than the EAC. In addition, the zinc concentration in the same samples is 1.6 times higher than the EAC. Once again, the soil samples collected from the surrounding areas of Sagarejo turned out to be overloaded with heavy metals (Graphs 2–3).

Two water samples were collected and used for analysis in Kakheti Region—from Ikalto village, and from the irrigation canal near Gurjaani (there are illegal landfill sites near them). Hydrochemical as well as microbiological and physicochemical properties of the samples from both locations were assessed. The results are shown in Tables 5–8 and Graph 4.

Table 5. The results of hydrochemical and microbiological analyses of the water samples collected from Ikalto

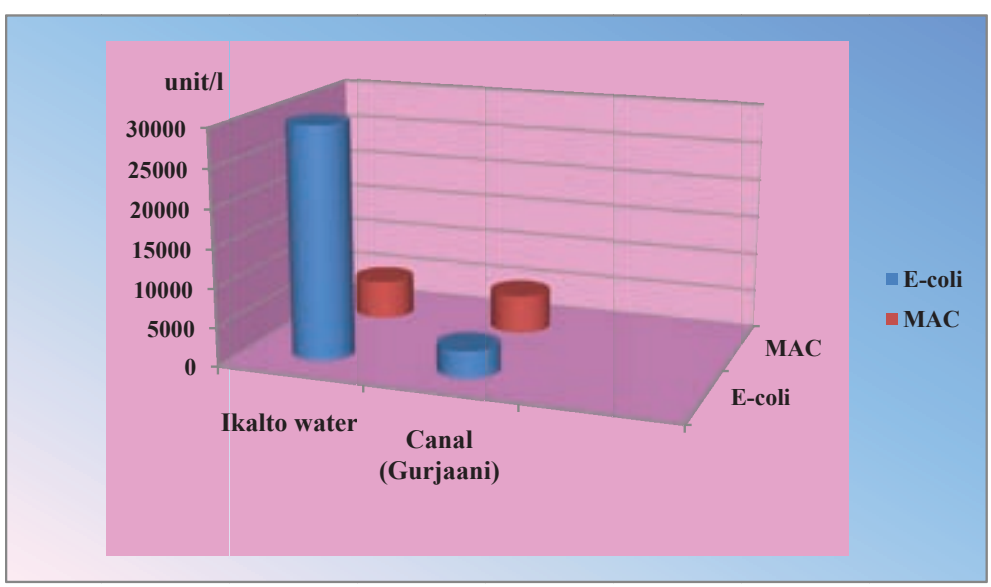
№	Parameters	Units	Measurement results
1	pH		8.6
2	Hydrogen carbonate	mg/l	100.04
3	Nitrate	mgN/l	0.162
4	Nitrite	mgN/l	0.093
5	Ammonium	mgN/l	**2.131**
6	Phosphate	mg/l	0.001
7	Sulfate	mg/l	43.61
8	Total coliforms	per liter	**70000**
9	E. coli	per liter	**30000**

Table 6. The results of hydrochemical and microbiological analyses of the water samples collected from Gurjaani irrigation canal

№	Parameters	Units	Measurement results
1	pH		8.08
2	Hydrogen carbonate	mg/l	234.28
3	Nitrate	mgN/l	1.023
4	Nitrite	mgN/l	0.164
5	Ammonium	mgN/l	0.132
6	Phosphate	mg/l	0.001
7	Sulfate	mg/l	31.367
8	total coliforms	per liter	**10000**
9	E. coli	per liter	3500

Table 7. Physicochemical properties of Gurjaani irrigation canal and Ikalto water (2014)

Sampling location	Sampling time	Coordinates	pH	Conductivity µS/cm	Salinity	Do, mg/l	T,°C
Irrigation canal (3 km from Gurjaani center)	21.11.2013	568940 4623145	8.08	297	0.01	5.31	9.9
The river flowing into Ikalto gully	29.04.2014	532596 4644794	8.2	368	0.04	3.97	21.0



Graph 4. The E. coli concentration of the water samples collected from Ikalto and Gurjaani irrigation canal

As we can see, based on the physicochemical properties (Table 7), the state of the surrounding areas is satisfactory (i.e. nonrecurring discharge of any kind has not occurred). Nonetheless, according to hydrochemical properties, the situation is different. For example, the ammonium concentration of the water samples collected from the Ikalto River is about 5.5 times higher than the MAC, E. coli – 6 times higher (30000 units), while the total coliform concentration equals to 70000 units per one liter of water. This indicates that the Ikalto River basin is in unsanitary conditions, which, in our opinion, is caused by the direct disposal of the major portion of wastes into the river. Accordingly, it means that the landfill site is located in the river gorge. As for the irrigation canal (Gurjaani), its microbiological state is significantly better than the quality of the Ikalto River because the irrigation canal is more isolated from the landfill site than the Ikalto River (Tables 5–6, and Graph 4).

Thus, the analyses showed that the Kakheti Region, namely the surrounding areas of Sagarejo and Gurjaani, is under rather intensive anthropogenic impact because of the uncontrolled landfill sites. This conclusion is based on the high concentration of pollutants (biogenic elements, intestinal bacteria, heavy metals) in both soil and water samples.

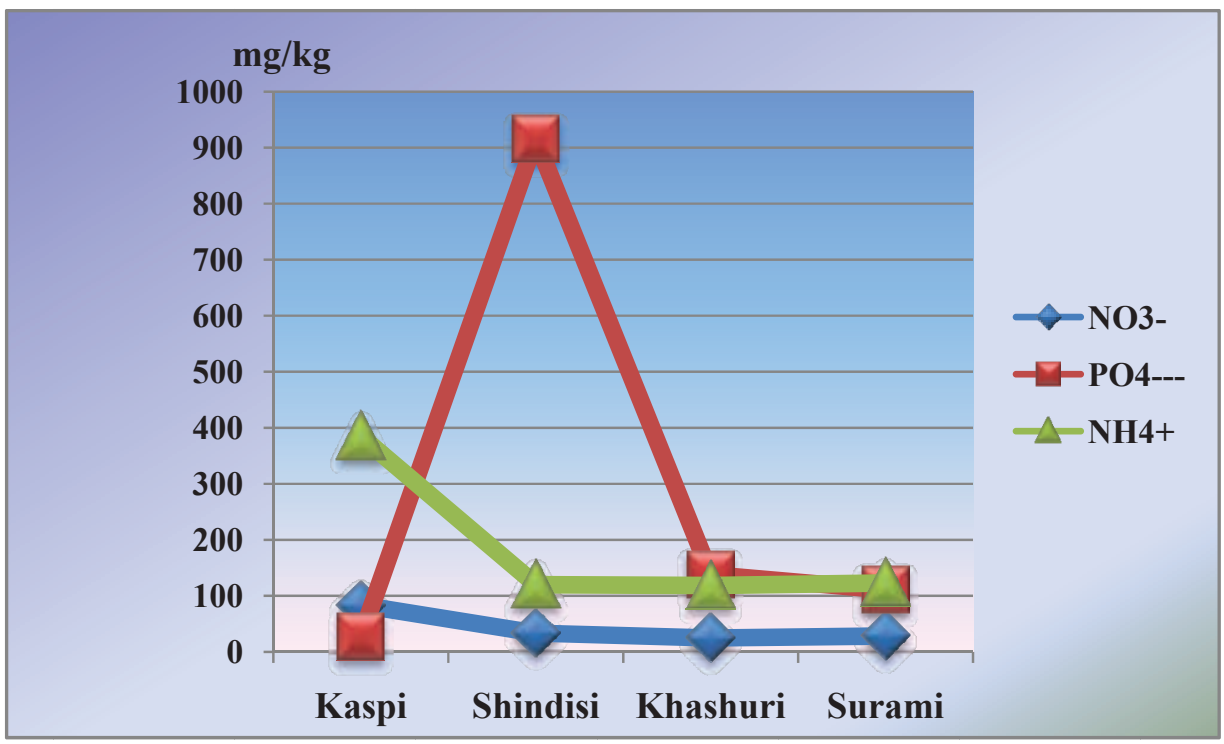
Shida Kartli Region

In Shida Kartli Region, the analysis samples were collected and assessed from the surrounding areas of the illegal landfill sites in Kaspi (Metekhi village), Gori (Shindisi), and Khashuri (city center) Regions. In this case, a section of the surrounding areas of Surami was chosen as a background. The results of hydrochemical and microbiological analyses are shown in Tables 8–13 and Graphs 4–11.

Table 8. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Shida Kartli Region

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	pH	HCO_3^- mg/kg	NO_2^- mgN/kg	NO_3^- mgN/kg	PO_4^{3-} mg/kg	NH_4^+ mgN/kg	SO_4^{2-} mg/kg
Kaspi, Metekhi village	24.01.2014	446159 4641793	561	7.50	659	6.1	**83.5**	**270.0**	**385**	1970
Shindisi (Gori Region)	29.02.2014	419016 4663873	720	7.21	4150	24.0	33.5	**915.5**	120	3050
Khashuri, the Suramula River (city center)	30.01.2014	383945 4650264	642	7.15	428	12.7	24.8	138.0	118.5	134
Surami (background)	30.01.2014	382302 4651986	725	6.95	422	11.4	28.5	110.8	122.8	142.8

Based on the hydrochemical data obtained, we can see that the surrounding areas of the illegal landfill sites chosen by us in Shida Kartli Region are more or less polluted with some forms of biogenic elements. Namely, in the soil samples collected from the surrounding areas of the illegal landfill site located in Shindisi village, the phosphate concentration is 8.5 times higher than in the background soil samples. As for the soil samples collected in Metekhi village (Kaspi Region), the nitrate and ammonium ion concentration in them is 3 times higher than the background data, while the phosphate concentration is 2.5 times higher (Graph. 5).



Graph 5. The biogenic element concentration in the soil samples and chosen background location collected in Shida Kartli Region

Based on the results of microbiological analysis of the samples collected in Shindisi and Metekhi villages, the research locations can be categorized as heavily polluted, while the surrounding areas of the Suramula River (Khashuri) as polluted. It should also be noted that pollution levels here are significantly worse than in the background location (Table 9).

Table 9. The results of microbiological analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Shida Kartli Region

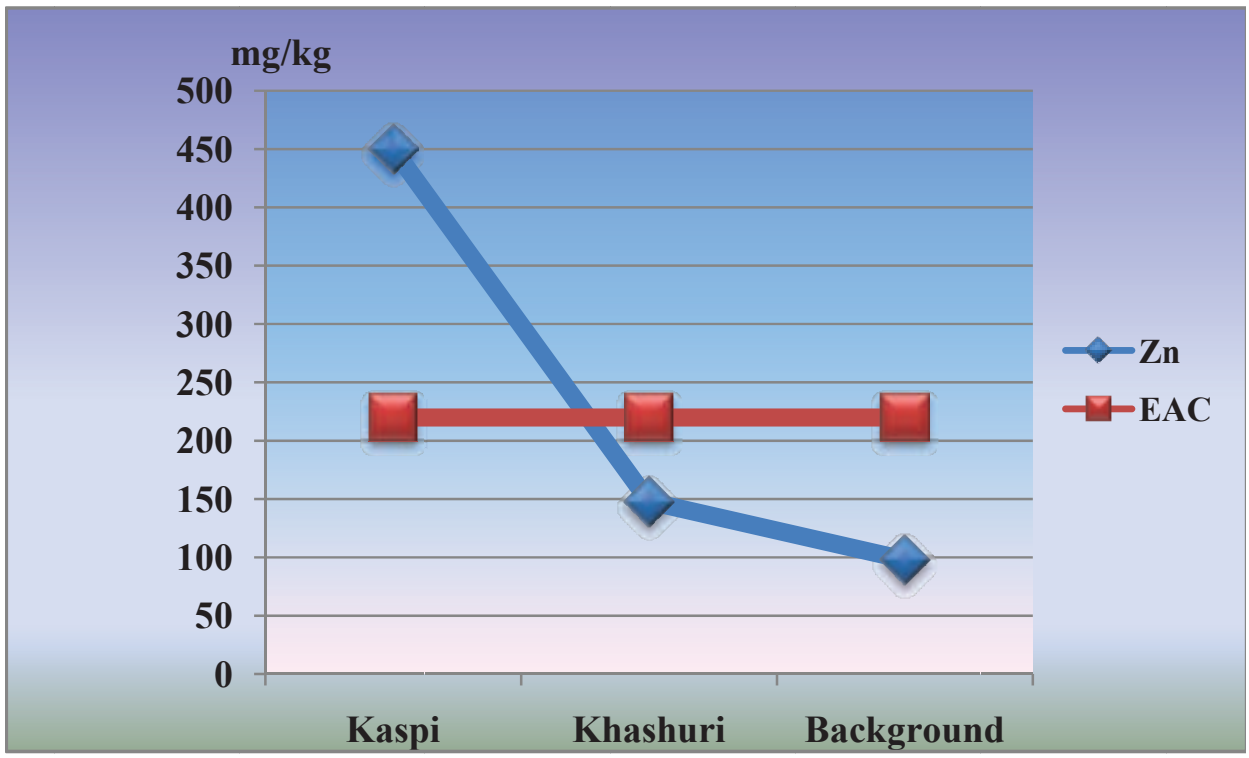
Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Total coliform titer	E. coli titer
Kaspi, Metekhi village	24.01.2014	446159 4641793	561	**0.0001**	**0.0001**
Shindisi (Gori Region)	29.02.2014	419016 4663873	720	**0.0001**	**0.0001**
Khashuri, the Suramula River	30.01.2014	383945 4650264	642	0.001	0.001
Surami (background)	30.01.2014	382302 4651986	725	0.01	0.01

Table 10 shows the concentration of heavy metals in the soil samples.

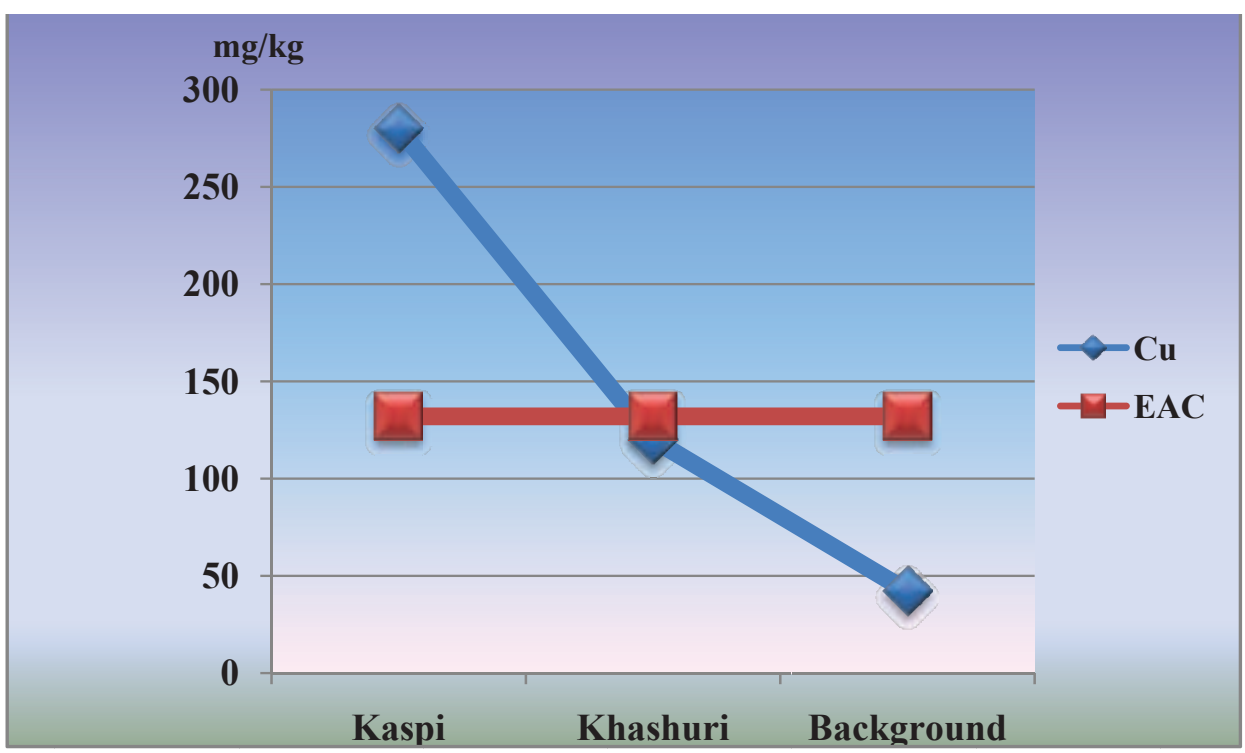
Based on the results (Table 10), it can be said that the Pb concentration in the soil samples collected in Metekhi village and Khashuri is two times higher than the Maximum Allowable Concentration, and 3 times higher than the background properties. In the samples collected in Metekhi village, the Cu concentration is 7 times higher than in the background, while the Zn concentration is 4.5 times higher. Thus, the soil in Shida Kartli turned out to be polluted with some of the heavy metals as well (see Graphs 6–8).

Table 10. The heavy metal (Cu, Zn, Pb, Cd) concentration in the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Shida Kartli Region

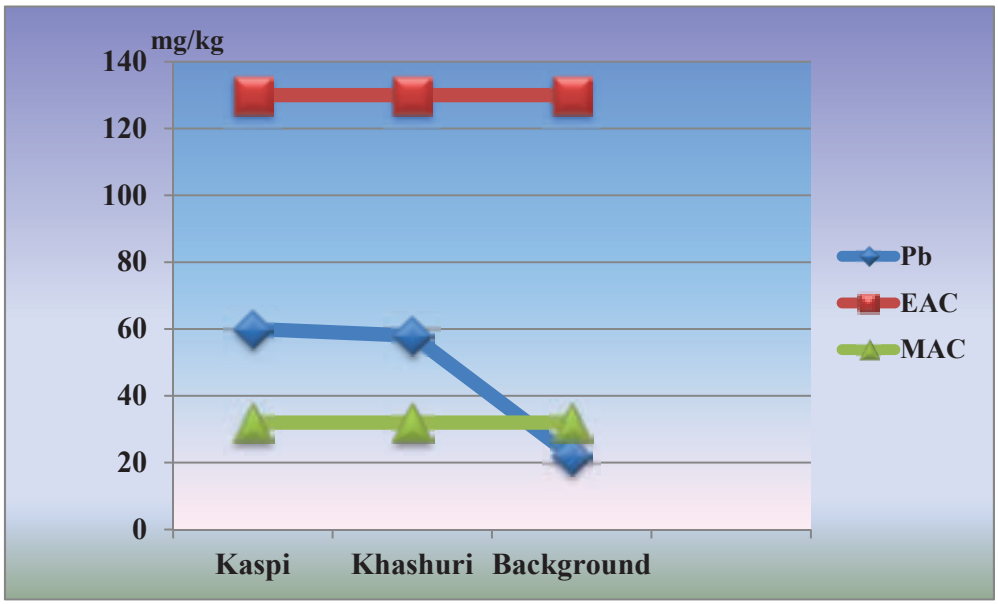
Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Cu, ppm	Zn, ppm	Pb, ppm	Cd, ppm
Kaspi, Metekhi village	24.01.2014	446159 4641793	561	**280**	**450**	60	< 2.5
Shindisi (Gori Region)	29.02.2014	419016 4663873	720	60	135	20	< 2.5
Khashuri, the Suramula River	30.01.2014	383945 4650264	642	120	148	58	< 2.5
Surami (background)	30.01.2014	382302 4651986	725	42	98	22	< 2.5
Maximum Allowable Concentration (MAC)						32	
Estimated Allowable Concentration				132	220	130	2.0



Graph 6. The zinc concentration in the soil samples collected in Shida Kartli



Graph 7. The copper concentration in the soil samples collected in Shida Kartli



Graph 8. The lead concentration in the soil samples collected in Shida Kartli

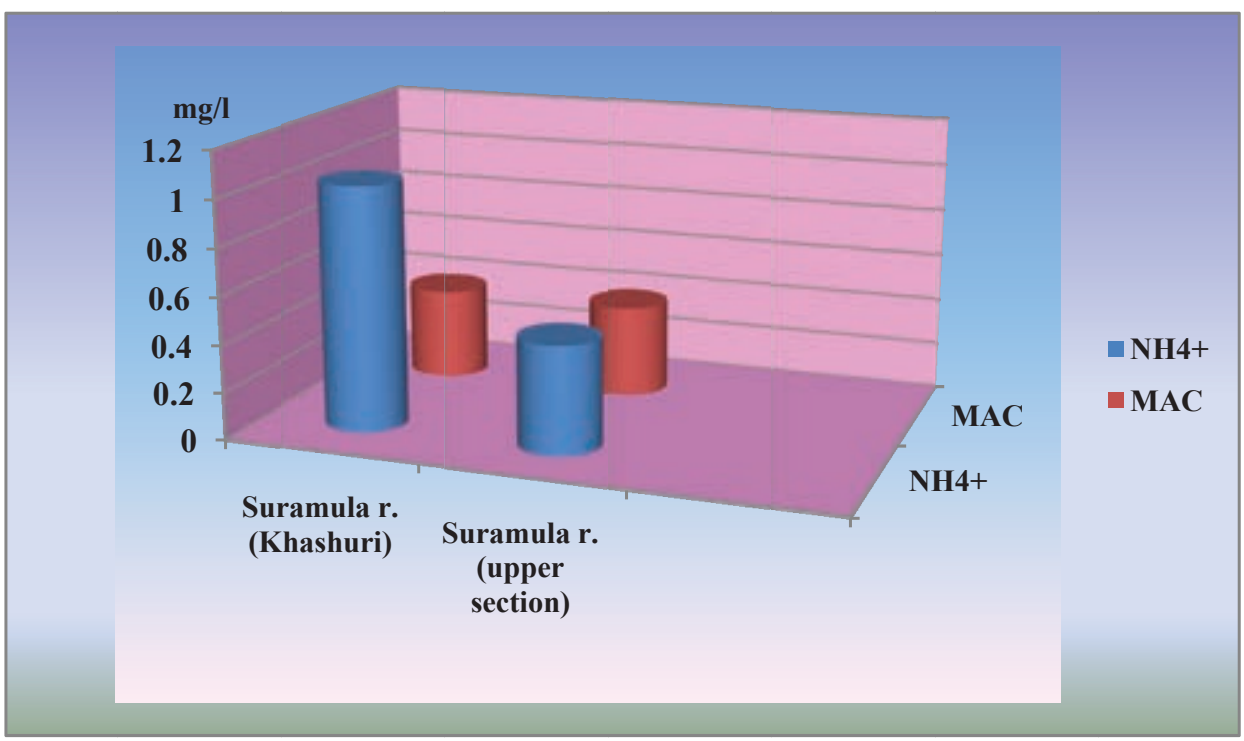
As for the physicochemical properties of the wastewater from the Suramula River and Metekhi village landfill sites, they are satisfactory (Table 11) and they do not display any sign of having been polluted by any nonrecurring discharge. According to the results of hydrochemical analysis (Table 12), the Suramula River (Khashuri, illegal landfill site) is notable for the high ammonium ion concentration (MAC), which is about 2.5 times higher (Graph 9) than in the background (upper section, 500 m from the city).

Table 11. Physicochemical properties of the wastewater from the Suramula River and Metekhi village landfill site (2014)

Sampling location	Sampling time	Coordinates	pH	Conductivity µS/cm	Salinity	Do	T,°C
Kaspi, Metekhi village (wastewater)	24.01.2014	446159 4641793	7.01	637	0.24	4.06	5.4
Khashuri, the Suramula River	30.01.2014	383945 4650264	7.23	337.4	0.03	5.91	5.9
Khashuri, upper section of the Suramula River (500 m from the city)	30.01.2014	383844 4650409	7.33	322	0.03	5.90	5.8

Table 12. The results of hydrochemical analysis of the water samples collected from the Suramula River and Metekhi village landfill wastewater (2014)

Sampling location	Sampling time	Coordinates	HCO_3^- mg/l	NO_2^- mgN/l	NO_3^- mgN/l	PO_4^{3-} mg/l	NH_4^+ mgN/l	SO_4^{2-} mg/l
Kaspi, Metekhi village (wastewater)	24.01.2014	446159 4641793	185.44	0.030	0.478	0.701	0.568	7.105
Khashuri, the Suramula River	30.01.2014	383945 4650264	119.56	0.001	0.098	0.878	**1.034**	7.321
Khashuri, upper section of the Suramula River (500 m from the city)	30.01.2014	383844 4650409	113.60	0.005	0.12	0.588	0.460	7.120



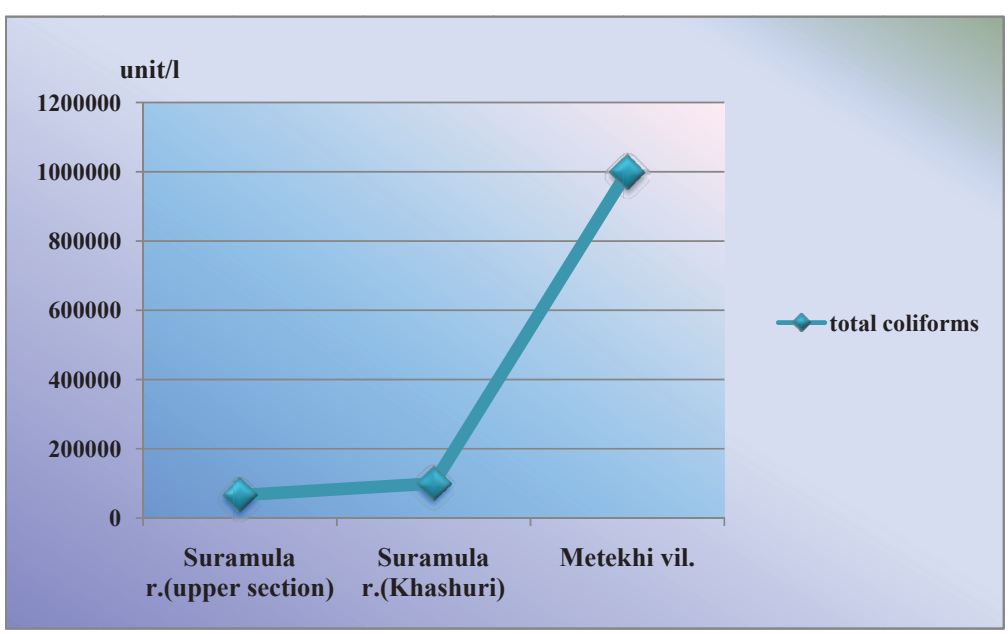
Graph 9. The ammonium ion the concentration of the water samples collected from the Suramula River

According to the microbiological data, the Metekhi village landfill wastewater turned out to be significantly polluted. Namely, million units of total coliforms were assessed per liter of water. This fact indicates that the wastewater—which flows into the Kura River and which is consumed by domestic animals—is particularly hazardous to human health. In our opinion, the existing landfill site in Metekhi village should be cleaned as soon as possible (Table 13; Graphs 10–11).

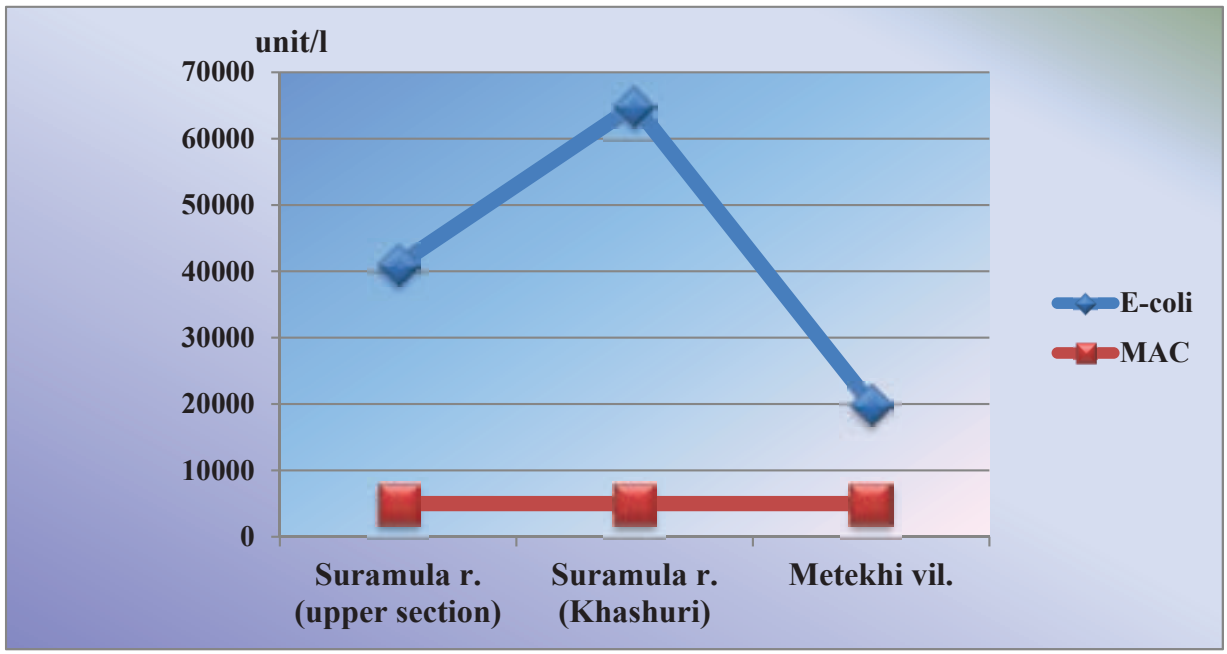
Thus, surface waters of Shida Kartli (the Suramula River, Metekhi village landfill wastewater) turned out to be extremely polluted according to the results of microbiological analysis. The E. coli concentration amounted to 70,000 units per liter, while total coliforms amounted to 1,000,000 units. This is a rather high index and needs special attention (Table 13).

Table 13. The results of microbiological analysis of the water samples collected from the Suramula River and Metekhi village wastewater

Sampling location	Sampling time	Coordinates	total coliforms (unit per liter)	norm	E. coli (unit per liter)	Norm	Used method
Kaspi, Metekhi village (wastewater)	24.01.2014	446159 4641793	**1000000**	-	20000	5000	Membrane filtration method
Khashuri, the Suramula River	30.01.2014	383945 4650264	**100000**	-	65000	5000	Membrane filtration method
Khashuri, upper section of the Suramula River (500 m from the city)	30.01.2014	383844 4650409	66000	-	41000	5000	Membrane filtration method



Graph 10. The total coliform concentration of the water samples collected from the Suramula River and Metekhi village landfill wastewater



Graph 11. The E. coli concentration of the water samples collected from the Suramula River and Metekhi village landfill wastewater

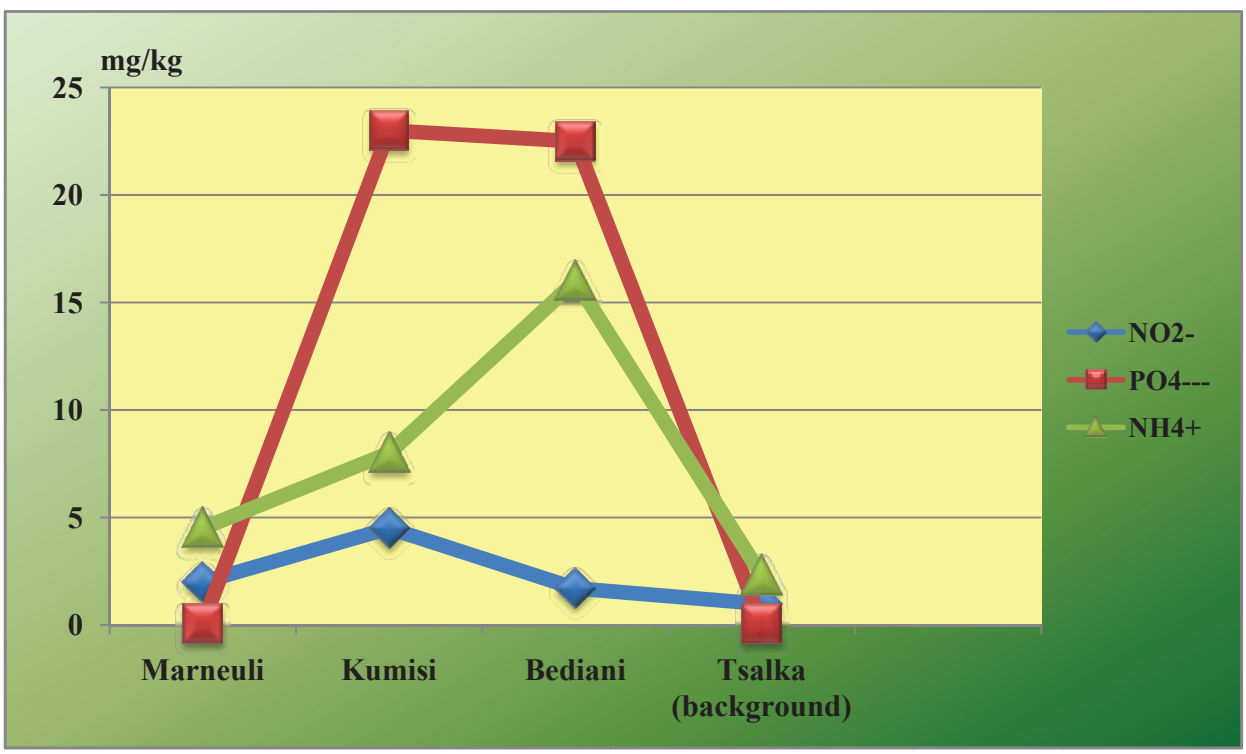
Kvemo Kartli Region

In Kvemo Kartli, the surrounding areas of three landfill sites (Marneuli Meat Factory, Kumisi – Bugami ravine, Bediani village) and one background location (Tsalka Region) were chosen for research. We performed hydrochemical and microbiological analyses of the soil samples and assessed the concentration of some heavy metals (Cu, Zn, Pb, Cd) in them. The results are shown in Tables 14–19 and Graphs 12–19.

Table 14. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Kvemo Kartli Region

Sampling location	Sampling time	Coordinates	Alti-tude (m.a.s.l.)	pH	HCO_3^- mg/kg	NO_2^- mgN/kg	NO_3^- mgN/kg	PO_4^{3-} mg/kg	NH_4^+ mgN/kg	SO_4^{2-} mg/kg
Marneuli, the surrounding areas of the Meat Factory (the Khrami River)	12.02.2014	484157 4592408	409	6.82	975	2.0	**57.5**	0.05	4. 5	3325
Gardabani Region, village Kumisi (Bugami ravine)	12.02.2014	483100 4607182	557	6.90	855	4.5	**65**	**23**	**8.0**	1330

Sampling location	Sampling time	Coordinates	Alti-tude (m.a.s.l.)	pH	HCO_3^- mg/kg	NO_2^- mgN/kg	NO_3^- mgN/kg	PO_4^{3-} mg/kg	NH_4^+ mgN/kg	SO_4^{2-} mg/kg
Bediani (the surrounding area of the Khrami River)	19.03.2014	437490 4599133	878	7.62	660	1.7	**8.0**	**22.5**	**16**	19
Tsalka Region (background)	19.03.2014	424199 4603765	1522	6.80	328	0.98	1.85	0.05	2.3	15.2



Graph 12. The biogenic element concentration in the soil samples and chosen background location collected in Kvemo Kartli Region

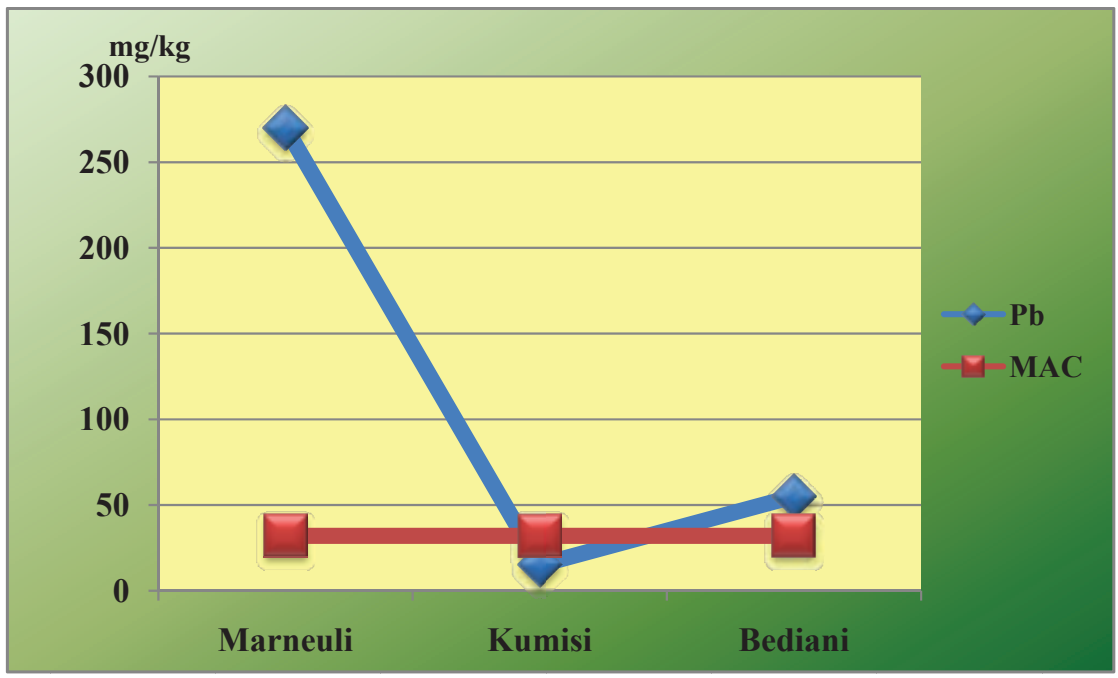
Based on the results (Table 14, Graph. 12), we can conclude that the soil samples collected from the surrounding areas of the landfill sites in Marneuli and Kumisi are polluted with all three forms of nitrogen. It should be particularly noted that the nitrate ion concentration in the samples from Marneuli and Kumisi is 30 times higher than in the background location, while in the samples from Bediani and Kumisi, the phosphate ion concentration is 450 times higher than in the background sample. In terms of microbiology, we can categorize the Bediani landfill site as heavily polluted (titer 0.0001, Table 15). It should also be mentioned that in the soil samples from Marneuli, the lead concentration is about

Table 15. The results of microbiological analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Kvemo Kartli Region

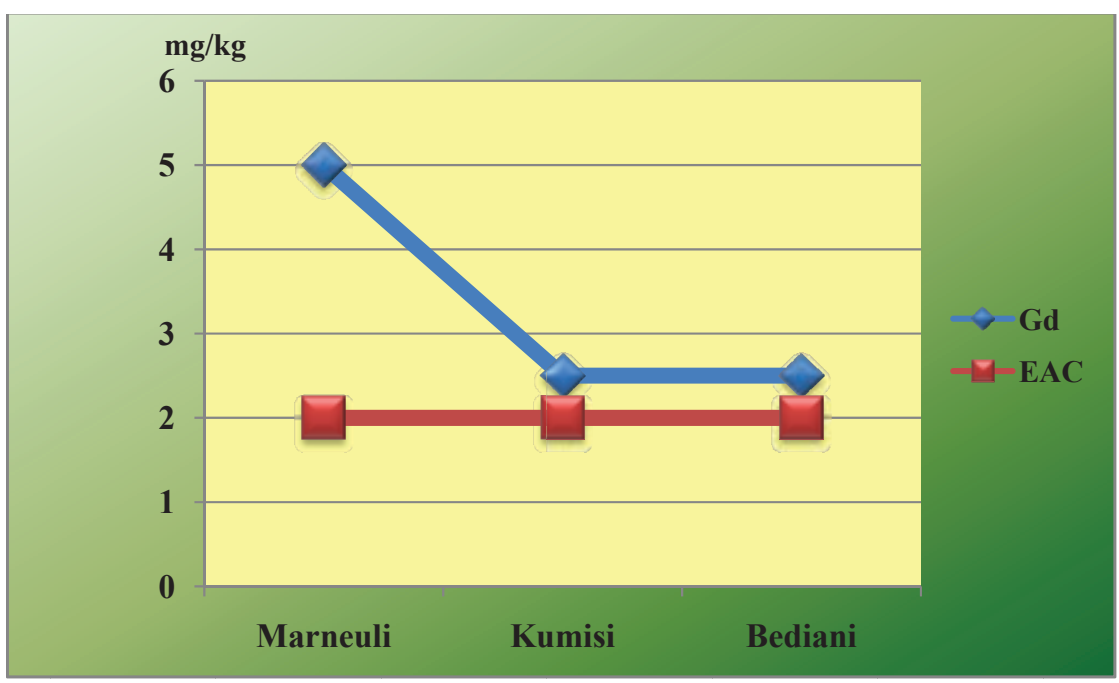
Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Total coliform titer	E. coli titer
Marneuli, the surrounding areas of the Meat Factory (the Khrami River)	12.02.2014	484157 4592408	409	0.01	0.01
Gardabani Region, village Kumisi (Bugami ravine)	12.02.2014	483100 4607182	557	0.01	0.01
Tsalka Region, Bediani (the surrounding areas of the Khrami River)	19.03.2014	437490 4599133	873	**0.0001**	**0.0001**
Tsalka Region (background)	19.03.2014	424199 4603765	1522	0.01	0.01

Table 16. The heavy metal (Cu, Zn, Pb, Cd) concentration in the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Kvemo Kartli Region

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Cu, ppm	Zn, ppm	Pb, ppm	Cd, ppm
Marneuli, the surrounding area of the Meat Factory (the Khrami River)	12.02.2014	484157 4592408	409	**375**	**550**	**270**	**5.0**
Gardabani Region, Kumisi village (Bugami ravine)	12.02.2014	483100 4607182	557	45	120	15	<2.5
Tsalka Region, Bediani (the surrounding area of the Khrami river)	19.03.2014	437490 4599133	873	45	140	55	<2.5
Tsalka Region (background)	19.03.2014	424199 4603765	1522	32	114	44	<2.5
Maximum Allowable Concentration (MAC)	-	-	-			32	
Estimated Allowable Concentration (EAC)	-	-	-	132	220	130	2.0



Graph 13. The lead concentration in the soil samples collected in Kvemo Kartli



Graph 14. The cadmium concentration in the soil samples collected in Kvemo Kartli

10 times higher than the Maximum Allowable Concentration and more importantly, the cadmium concentration in the samples is 2.5 times higher than the Estimated Allowable Concentration (Graphs 13–14).

In the same region, we performed hydrochemical, physicochemical, and microbiologi-

cal analyses of the water samples collected from several spots of the Khrami River. The results are shown in Tables 17–19 and Graphs 15–19. It should be noted that the pollution level of the river near the landfill sites is insignificantly increased compared to other cases. That is, in this specific case, the role of the landfill sites in the pollution process of the river water is less substantial (except the case, when we observed 35,000 units of Faecal streptococci in Marneuli and relatively high concentration of ammonium in the same location [Graphs 17–19]).

Table 17. The results of hydrochemical analysis of the water samples collected from the Khrami River (2014)

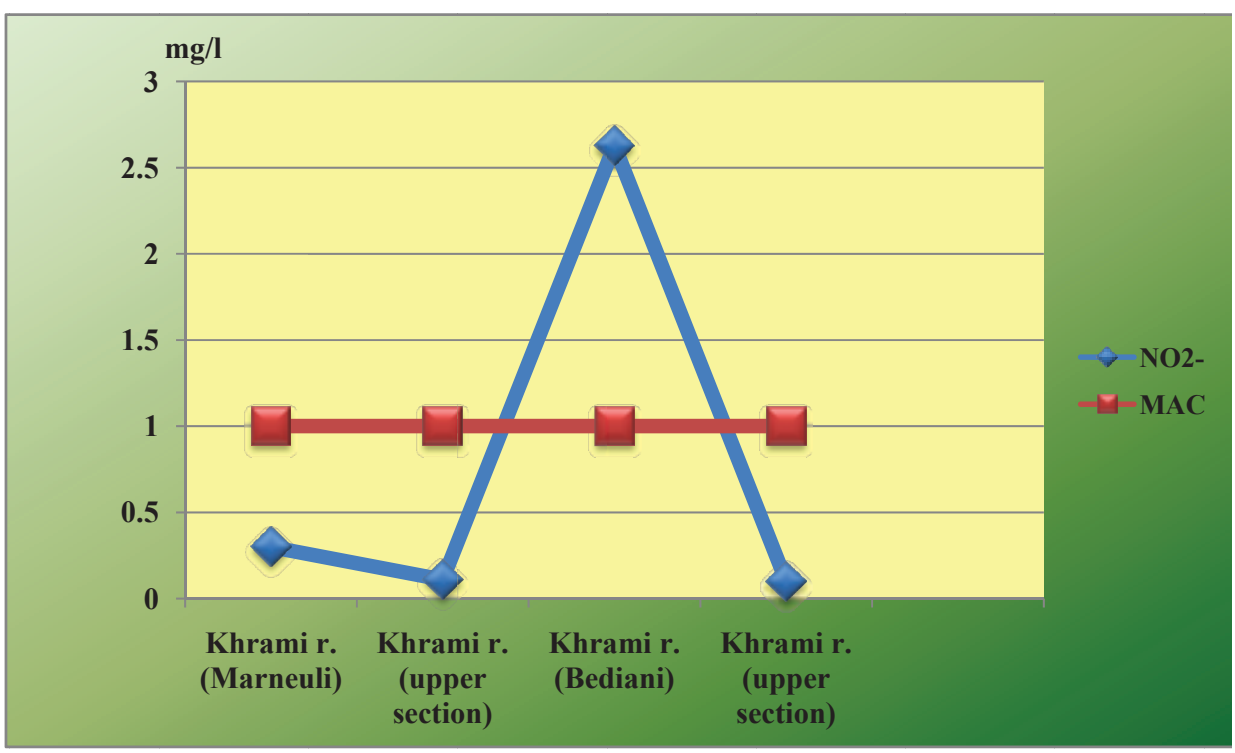
Sampling location	Sampling time	Coordinates	HCO_3^- mg/l	NO_2^- mgN/l	NO_3^- mgN/l	PO_4^{3-} mg/l	NH_4^+ mgN/l	SO_4^{2-} mg/l
The Khrami River (Marneuli, the surrounding area of the Meat Factory)	12.02.2014	484157 4592408	283.04	0.299	**2.318**	0.001	**0. 816**	208.31
The Khrami River, upper section (500 m from the city)	12.02.2014	484371 4592208	210.0	0.11	0.845	0.001	0. 303	177.0
The Khrami River (Bediani, the surrounding area of the landfill site)	19.03.2014	437490 4599133	119.56	2.628	**4.928**	0.001	0.303	14.24
The Khrami River, upper section (1000 m from Bediani)	19.03.2014	436830 4600057	168.83	0.099	1.223	0.001	0.240	14.55

Table 18. The results of physicochemical analysis of the water samples collected from the Khrami River (2014)

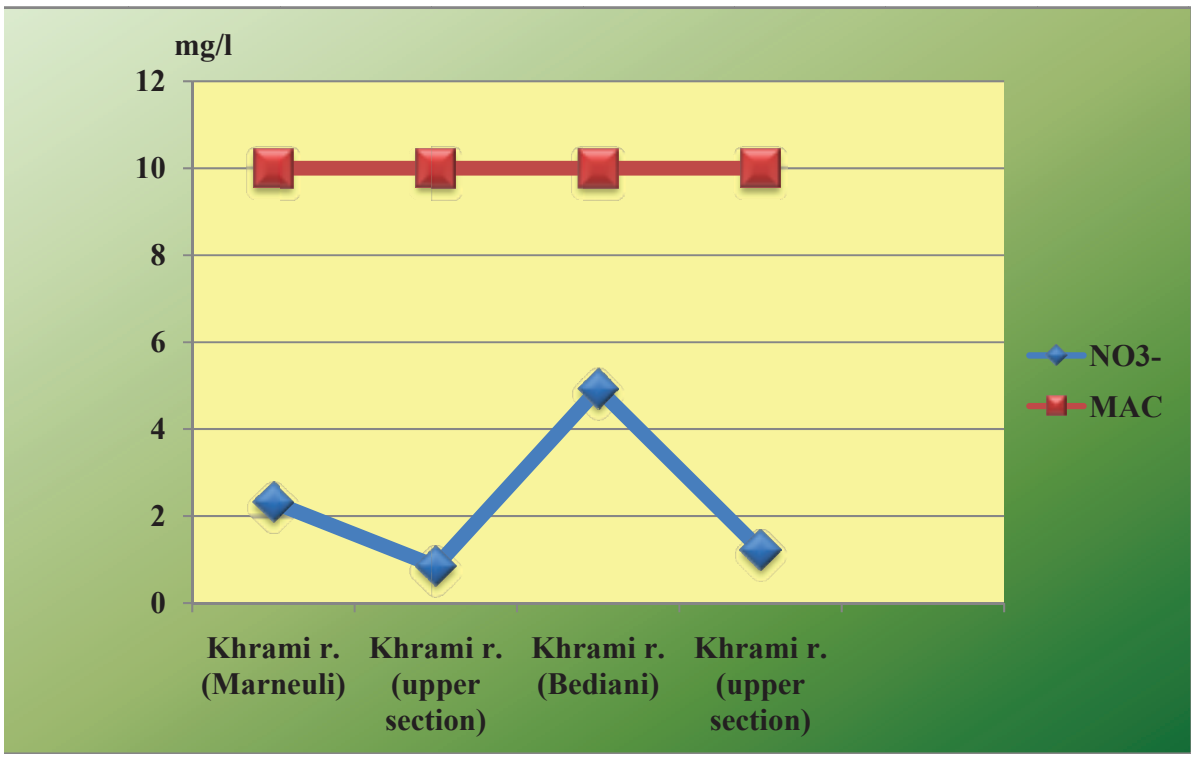
Sampling location	Sampling time	Coordinates	pH	Conductivity µS/cm	Salinity	Do	T,°C
The Khrami River (Marneuli, the surrounding area of the Meat Factory)	12.02.2014	484157 4592408	6.72	286	0.02	5.1	10.2
The Khrami River, upper section (500 m from the city)	12.02.2014	436830 4600057	6.98	276	0.02	5.0	9.9
The Khrami River (Bediani, the surrounding area of the landfill site)	19.03.2014	437490 4599133	8.15	252	0.015	4.95	9.8
The Khrami River, upper section (1000 m from Bediani)	19.03.2014	436830 4600057	8. 08	202	0.015	5.02	9.7

Table 19. The results of microbiological analysis of the water samples collected from the Khrami River

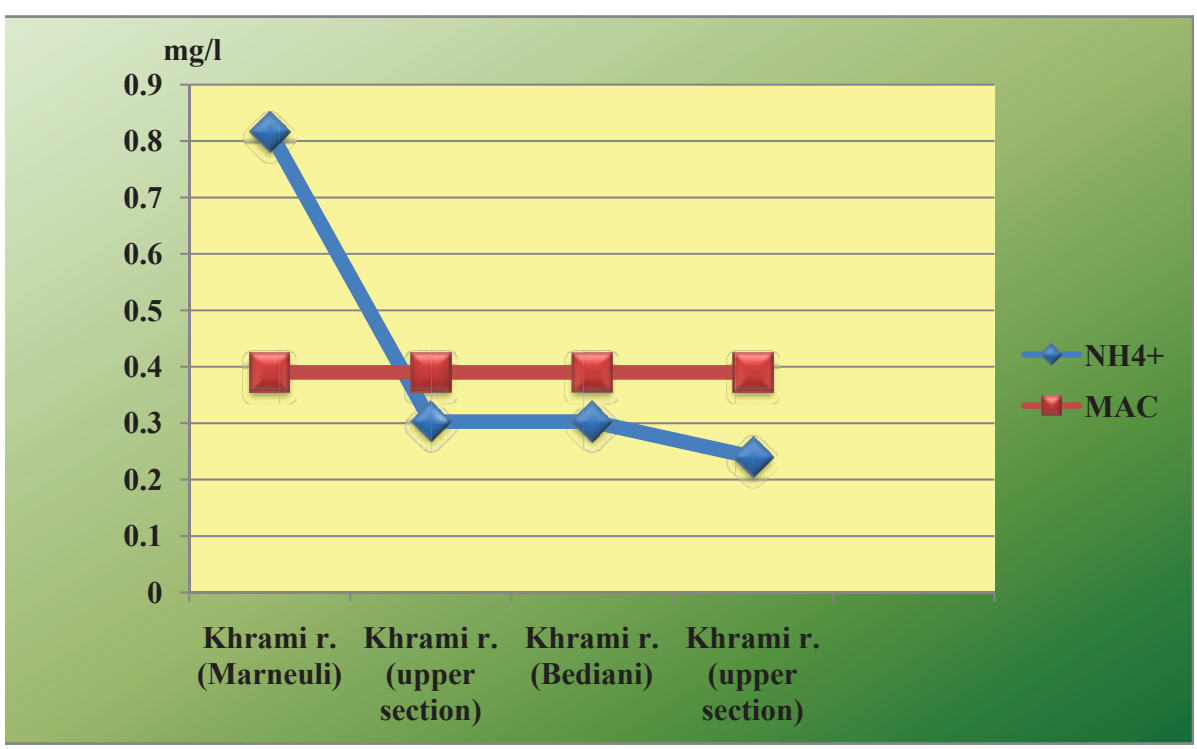
Sampling location	Sampling time	Coordinates	Total coliforms (unit per liter)	Norm	E. coli (unit per liter)	Norm	Used method
Next to the Marneuli Meat Factory (the Khrami River)	12.02.2014	484157 4592408	350000	-	1500	5000	Membrane filtration method
The Khrami River, upper section (500 m from the city)	12.02.2014	436830 4600057	8000	-	1350	5000	Membrane filtration method
Tsalka Region, Bediani (the surrounding area of the Khrami River)	19.03.2014	437490 4599133	250	-	30	5000	Membrane filtration method
The Khrami River (Bediani, the surrounding area of the landfill site)	19.03.2014	436830 4600057	280	-	32	5000	Membrane filtration method



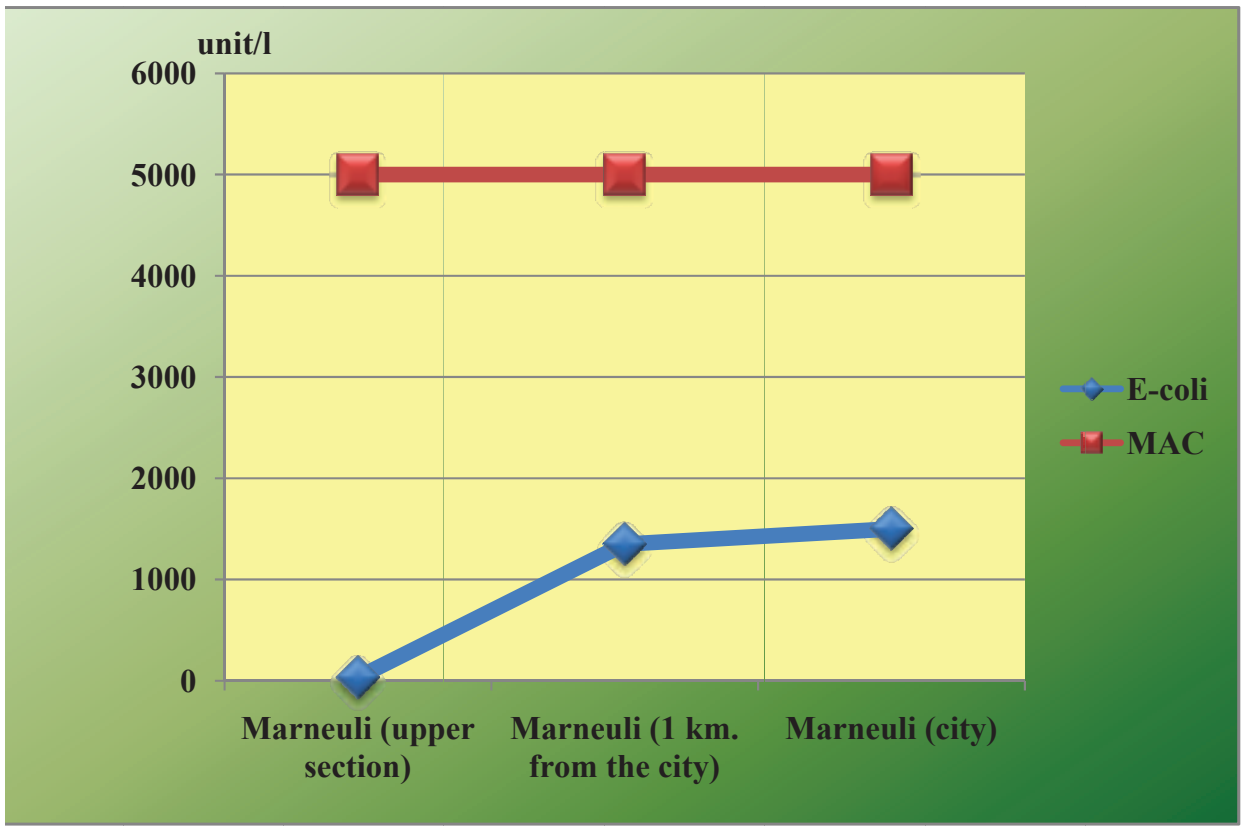
Graph 15. Dynamics of changes in the concentration of nitrite ions in the water samples collected from the Khrami River, based on the flow direction



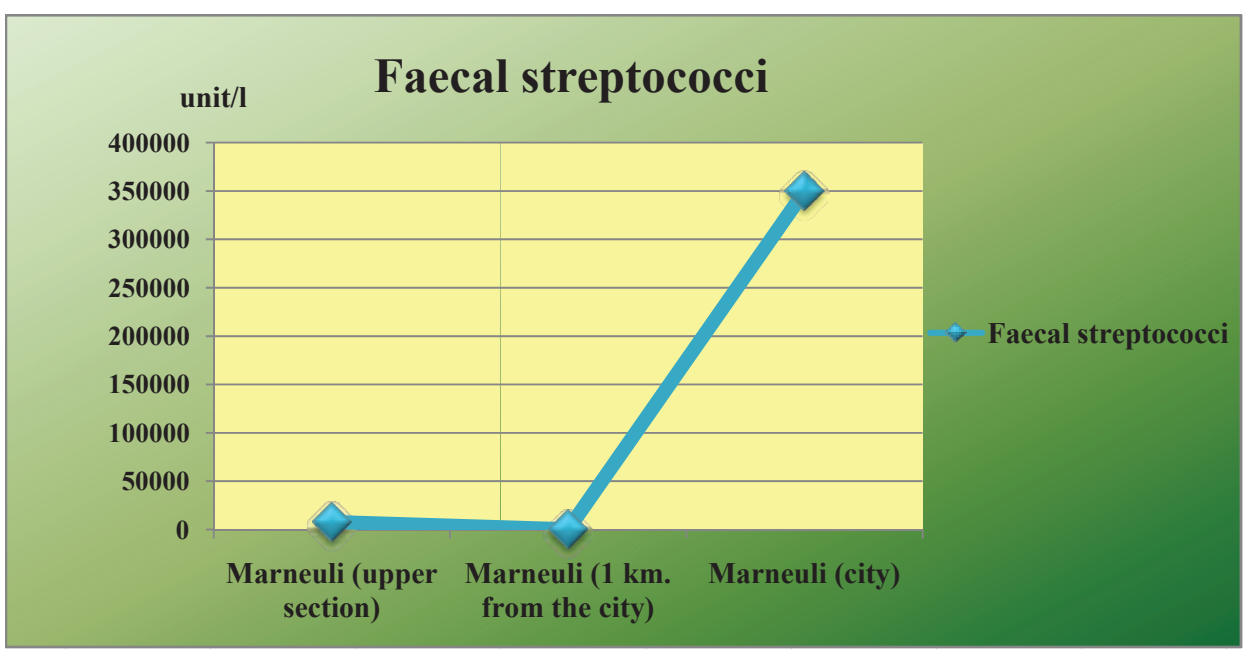
Graph 16. Dynamics of changes in the concentration of nitrate ions in the water samples collected from the Khrami River, based on the flow direction



Graph 17. Dynamics of changes in the concentration of ammonium ions in the water samples collected from the Khrami River, based on the flow direction



Graph 18. Dynamics of changes in the concentration of E. coli in the water samples collected from the Khrami River, based on the flow direction



Graph 19. Dynamics of changes in the concentration of Faecal streptococci in the water samples collected from the Khrami River, based on the flow direction

Thus, in Kvemo Kartli Region, exceptional was the state of the Marneuli landfill site (near the Meat Factory). In the collected soil samples, there was high concentration of lead and most importantly, of cadmium. In our opinion, this needs very special attention.

Samtskhe-Javakheti Region

The fieldwork continued in Samtskhe-Javakheti Region, where we selected the following illegal (uncontrolled) landfill sites for analysis: Akhaltsikhe (Kvabliani), Aspindza (Pia village), Ninotsminda (the middle section of Didi Khanchali) as well as another area in Aspindza for the background analysis. The results of hydrochemical and microbiological analyses are shown in Tables 20–25 and Graphs 20–26.

Table 20. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Samtskhe-Javakheti Region

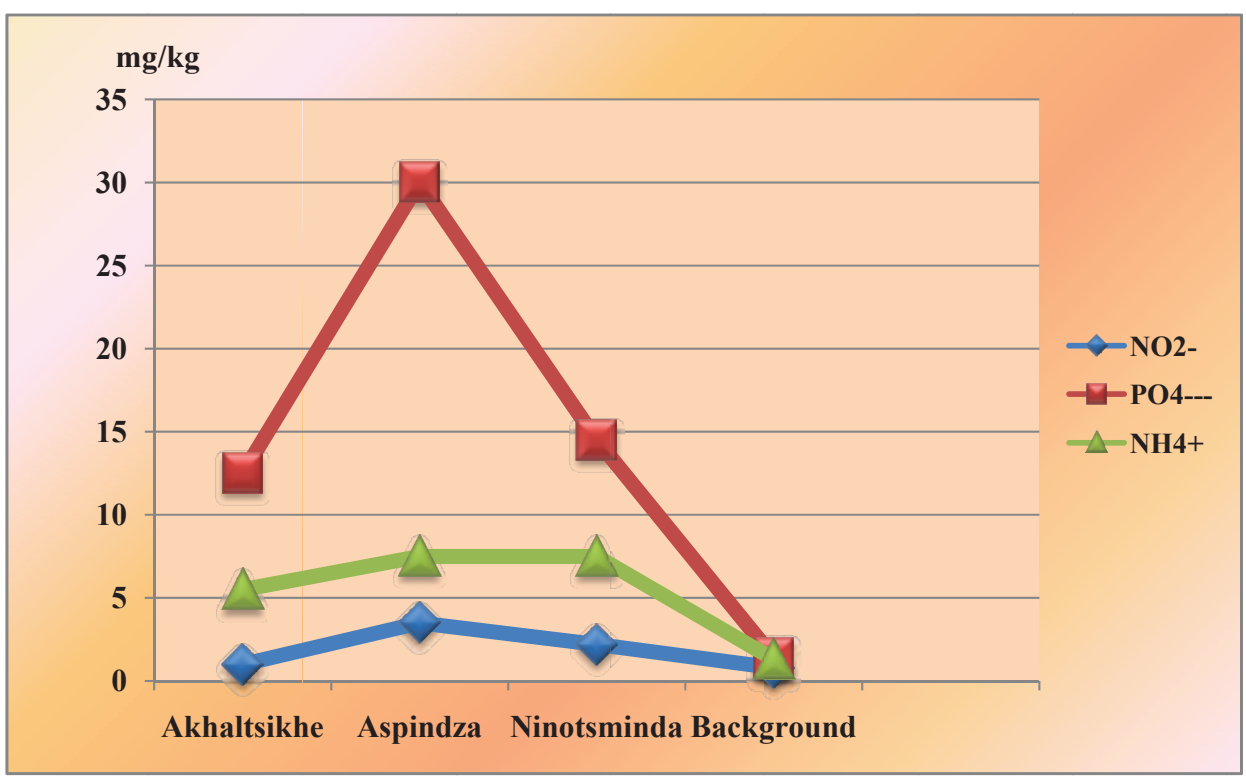
Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	pH	HCO_3^- mg/kg	NO_2^- mgN/kg	NO_3^- mgN/kg	PO_4^{3-} mg/kg	NH_4^+ mgN/kg	SO_4^{2-} mg/kg
Akhaltsikhe (Kvabliani), the surrounding area of the Potskhovi River	11.03.2014	330264 4611810	976	7.01	683	1	20	12.5	5.5	941.5
Aspidza, Pia village (the surrounding area of the Kura River)	21.03.2014	359054 4588465	1173	6.9	537	3.5	**106.5**	**30**	**7.5**	430
Ninotsminda, middle section of Didi Khanchali	26.03.2014	381937 4567864	1953	6.98	415	2.2	5	14.5	7.5	24
The surrounding area of Aspindza, 1400 m (background)	21.03.2014	355083 4602956	1100	6.8	323	0.8	2.8	1.4	1.3	42

Similarly to the previous cases, the soil samples collected from the surrounding areas are more heavily polluted with biogenic elements than the background location. The surrounding area of the landfill site in Pia village, Aspindza Region is particularly notable in this respect. In the soil samples, the nitrate ion concentration is 35 times higher than the background values; the phosphate concentration is 20 times higher, while the ammonium concentration is 6.5 times higher (Table 20). In addition, the microbiological analysis revealed that the soil samples collected in the surrounding areas of Aspindza and Akhaltsikhe, are polluted with total coliforms and E. coli (Table 21).

In the samples collected from the abovementioned locations, we have also assessed the heavy metal concentration. The results are shown in Table 22 and Graphs 21–23.

Table 21. The results of microbiological analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Samtskhe-Javakheti Region

Sampling location	Sampling time	Coordinates	Total coliform titer	E. coli titer
Akhaltsikhe (Kvabliani), the surrounding area of the Potskhovi river	11.03.2014	330264 4611810	0.001	0.001
Aspindza, Pia village (the surrounding area of the Kura River)	21.03.2014	359054 4588465	0.001	0.001
Ninotsminda, middle section of Didi Khanchali	26.03.2014	381937 4567864	0.01	0.01
The surrounding area of Aspindza, 1100 m (background)	21.03.2014	355083 4602956	0.01	0.01



Graph 20. The biogenic element concentration in the soil samples and chosen background location collected in Samtskhe-Javakheti Region

From the results revealing the heavy metal concentration in the samples collected from the surrounding areas of the landfill sites in Samtskhe-Javakheti Region, special attention should be paid to the fact that in Akhaltsikhe, the concentration of cadmium was 4.5 ppm. This value is 2.5 times higher than the Estimated Allowable Concentration as well as the values of the background samples. It should also be noted that in the soil samples collected from the surrounding area of Akhaltsikhe (Kvabliani), the copper concentration is 3 times higher than the Maximum Allowable Concentration (Table 22).

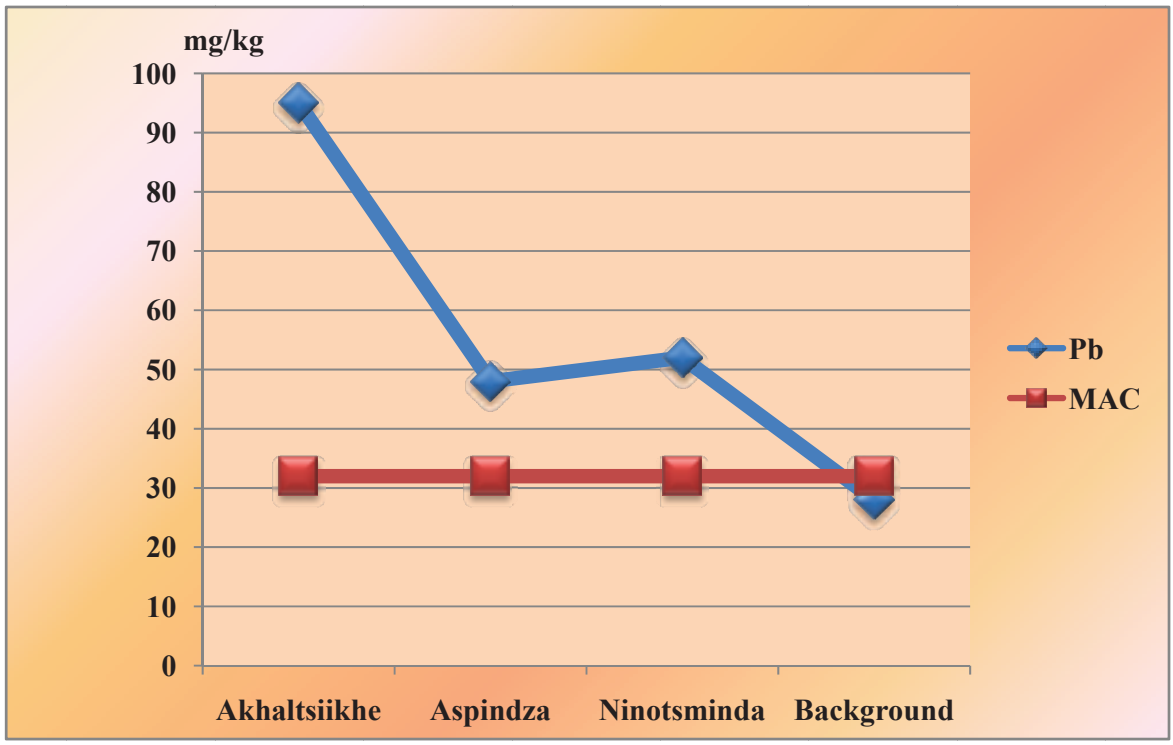
The results of hydrochemical, microbiological, and physicochemical analyses of the samples collected from the Potskhovi River—along with some other results—are shown in Tables 23–25 and Graphs 24–26.

Table 22. The heavy metal (Cu, Zn, Pb, Cd) concentration in the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Samtskhe-Javakheti Region

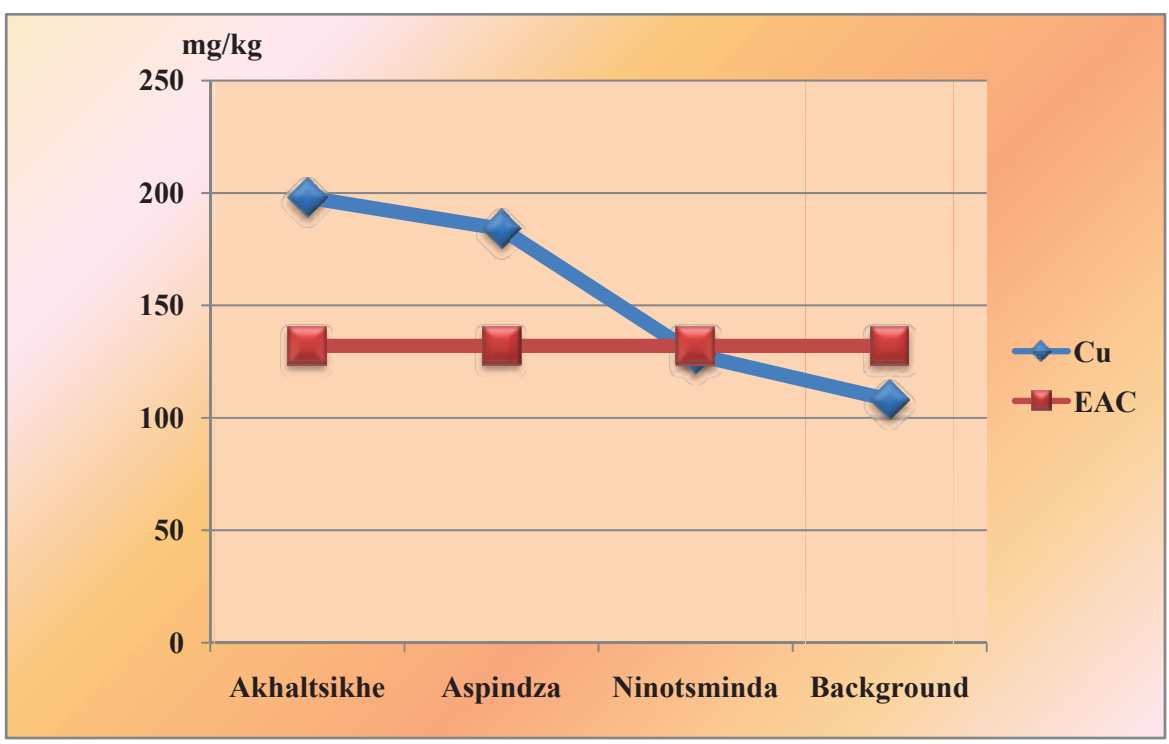
Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Cu, ppm	Zn, ppm	Pb, ppm	Cd, ppm
Akhaltsikhe (Kvabliani), the surrounding area of the Potskhovi Rver	11.03.2014	330264 4611810	976	198	345	**95**	**4.5**
Aspidza, Pia village (the surrounding area of the Kura River)	21.03.2014	359054 4588465	1173	184	278	48	<2.5
Ninotsminda, middle section of Didi Khanchali	26.03.2014	381937 4567864	1953	128	215	**52**	<2.5
The surrounding area of Aspindza, 1100 m (background)	21.03.2014	355083 4602956	1100	108	198	28	<2.5
Maximum Allowable Concentration (MAC)	-	-	-			32	
Estimated Allowable Concentration (EAC)	-	-	-	132	220	130	2.0

Table 23. The results of hydrochemical analysis of the water samples collected from the Potskhovi River (2014)

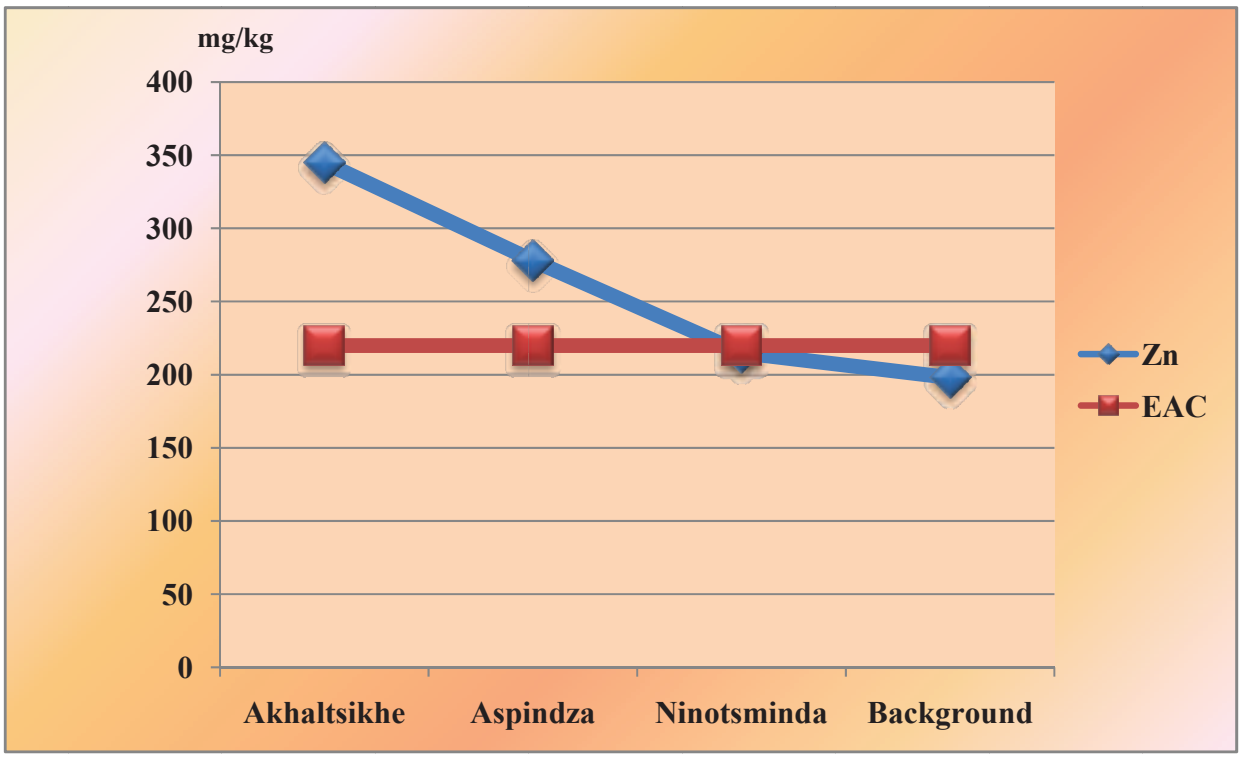
Sampling location	Sampling time	Coordinates	HCO_3^- mg/l	NO_2^- mgN/l	NO_3^- mgN/l	PO_4^{3-} mg/l	NH_4^+ mgN/l	SO_4^{2-} mg/l
The Potskhovi River (Kvabliani)	11.03.2014	330264 4611810	70.76	0.491	0.033	0.164	0.607	11.15
The Potskhovi River, upper section (500 m from Kvabliani)	11.03.2014	329731 4611931	55.42	0.122	0.022	0.08	0.480	10.22



Graph 21. The lead concentration in the soil samples collected in Samtskhe-Javakheti Region



Graph 22. The copper concentration in the soil samples collected in Samtskhe-Javakheti Region



Graph 23. The zinc concentration in the soil samples collected in Samtskhe-Javakheti Region

Table 24. The results of physicochemical analysis of the water samples collected from the Potskhovi River (2014)

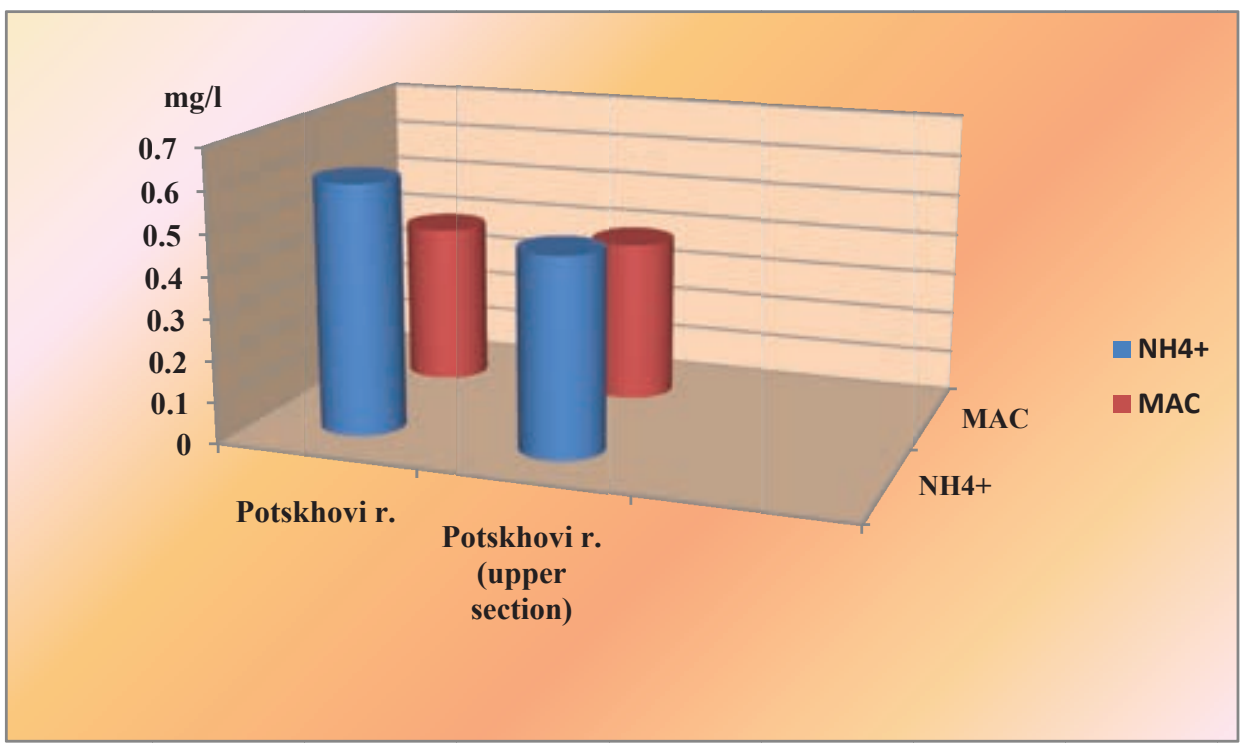
Sampling location	Sampling time	Coordinates	pH	Conductivity µS/cm	Salinity	Do	T,°C
The Potskhovi River (Kvabliani)	11.03.2014	330264 4611810	8.23	131.5	0.025	5.32	6.5
The Potskhovi River, upper section (500 m from Kvabliani)	11.03.2014	329731 4611931	8.16	120	0.025	5.0	6.2

Table 25. The results of microbiological analysis of the water samples collected from the Potskhovi River (2014)

Sampling location	Sampling time	Coordinates	Total coliforms (unit per 1 liter)	Norm	E. coli (unit per 1 liter)	Norm	Method used
The Potskhovi River (Kvabliani)	11.03.2014	330264 46118100	32000	-	31500	5000	Membrane filtration method
The Potskhovi River, upper section (500 m from Kvabliani)	11.03.2014	329731 4611931	12000	-	8500	5000	Membrane filtration method

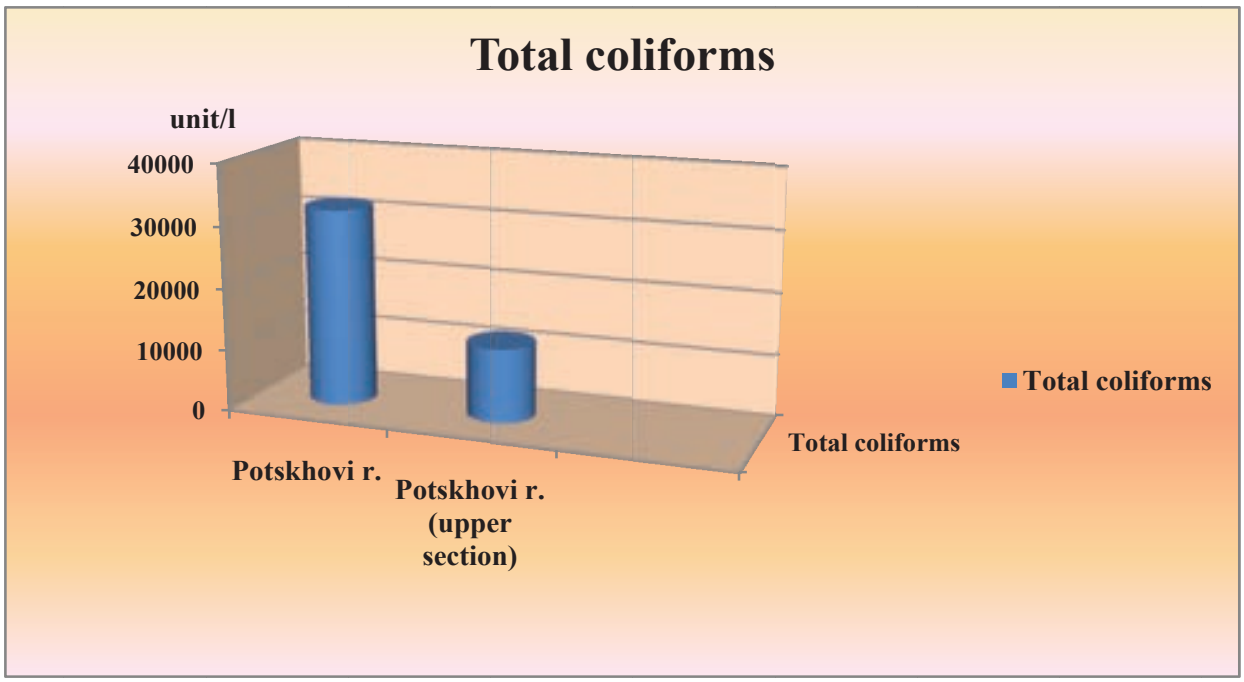
We can see that the water samples collected from the Potskhovi River—that flows near one of the landfill sites (Kvabliani)—are polluted with ammonium ions and intestinal bacteria. That is, the concentration is several times higher than the Maximum Allowable Concentration. The concentration of total coliforms and E. coli is 2–3 times higher than the background location values (Graphs 24–26).

This once again shows that uncontrolled landfill sites in Eastern Georgia, which are located in the gorges, on the banks of the rivers, play a significant role in the pollution process of surface waters. Based on this, it can be said that such locations should be immediately freed from the landfill sites and thoroughly cleaned.

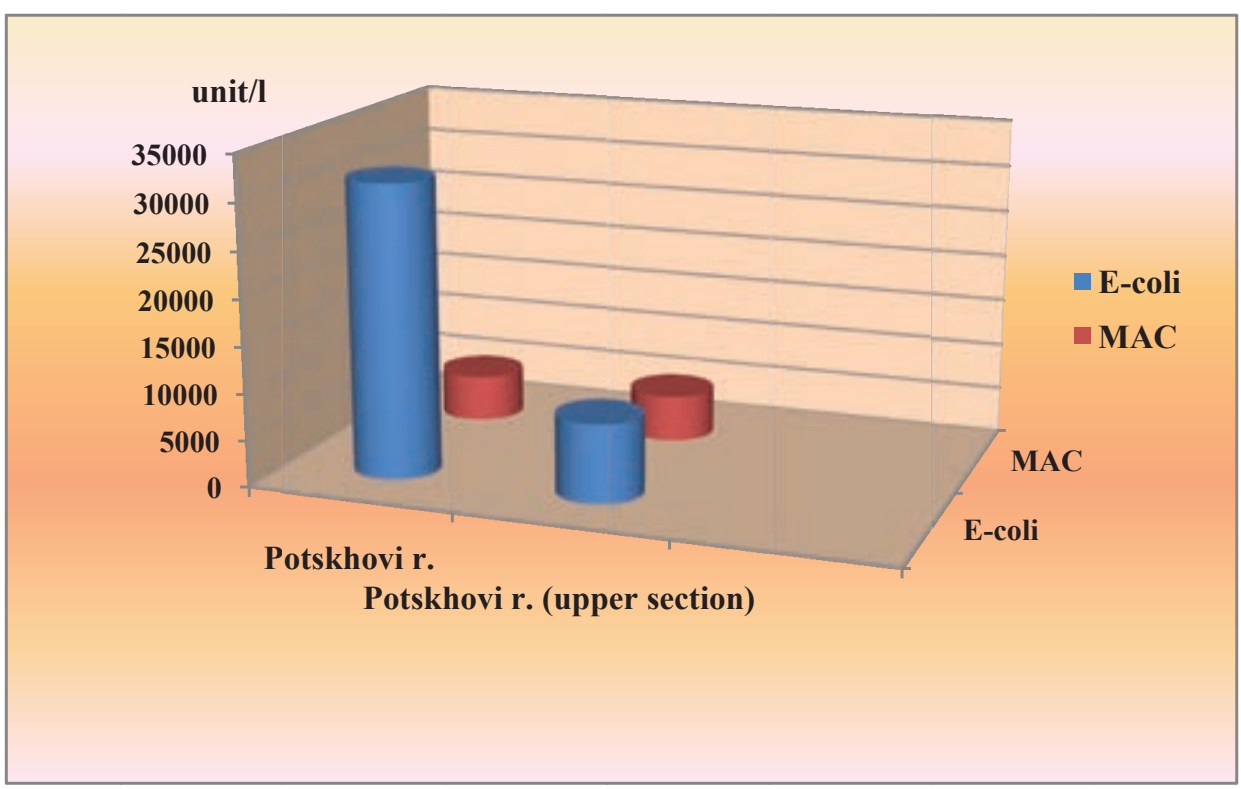


Graph 24. The ammonium ion concentration of the water samples collected from the Potskhovi River (2014)

Thus, the surrounding areas of Aspindza and Akhaltsikhe landfill sites turned out to be rather polluted with both biogenic elements and all four types of heavy metals. More importantly, the increased concentration of a toxic element cadmium has been assessed in the soil samples.



Graph 25. The total coliform concentration of the water samples collected from the Potskhovi River (2014)



Graph 26. The E. coli concentration of the water samples collected from the Potskhovi River (2014)

Mtskheta-Mtianeti Region

In Mtskheta-Mtianeti Region, the analysis samples (soil, surface water) were collected in Dusheti. Namely, we selected the surrounding area of the landfill located in the gully as well as the gully water and a background location. The results are shown in Tables 26–31.

Table 26. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Dusheti Region

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	pH	HCO_3^- mg/kg	NO_2^- mgN/kg	NO_3^- mgN/kg	PO_4^{3-} mg/kg	NH_4^+ mgN/kg	SO_4^{2-} mg/kg
Dusheti (gully)	06.03.2014	473885 4659730	868	7.04	500	0.5	0.05	0.005	1.5	40
Dusheti (background)	06.03.2014	473948 4659787	872	7.02	420	0.25	0.03	0.005	1.1	32

Table 27. The results of microbiological analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Dusheti Region

Sampling location	Sampling time	Coordinates	Total coliform titer	E. coli titer
Dusheti (gully)	06.03.2014	473885 4659730	0.01	0.01
Dusheti (background)	06.03.2014	473948 4659787	0.01	0.01

Table 28. The heavy metal (Cu, Zn, Pb, Cd) concentration in the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Dusheti Region

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Cu, ppm	Zn, ppm	Pb, ppm	Cd, ppm
Dusheti (gully)	06.03.2014	473885 4659730	868	48	102	27	< 2.5
Dusheti (background)	06.03.2014	473948 4659787	872	38	88	22	< 2.5
Maximum Allowable Concentration (MAC)	-	-	-			32	
Estimated Allowable Concentration (EAC)	-	-	-	132	220	130	2.0

Table 29. Physicochemical properties of Dusheti gully water (2014)

Sampling location	Sampling time	Coordinates	pH	conductivity	salinity µS/cm	Do	T,°C
Gully water (Dusheti)	06.03.2014	473885 4659730	7.58	416	0.025	5.06	14.7

Table 30. The results of hydrochemical analysis of the water samples collected from Dusheti gully water (2014)

Sampling location	Sampling time	Coordinates	HCO_3^- mg/l	NO_2^- mgN/l	NO_3^- mgN/l	PO_4^{3-} mg/l	NH_4^+ mgN/l	SO_4^{2-} mg/l
Gully water (Dusheti)	06.03.2014	473885 4659730	131.76	0.001	2.069	0.001	0.591	89.144

Table 31. The results of microbiological analysis of the water samples collected from Dusheti gully water

Sampling location	Sampling time	Coordinates	Total coliforms (unit per 1 liter)	Norm	E. coli (unit per 1 liter)	Norm	Used method
Gully water (Dusheti)	06.03.2014	473885 4659730	38000	-	15000	5000	Membrane filtration method

The results of the analyses of the soil samples collected in Dusheti Region indicate that according to the hydrochemical data, the surrounding area of the landfill site in the gully is not significantly polluted (Tables 26–28), although according to the microbiological results (Table 27), it can be categorized as polluted. As for the gully water, a certain amount of both total coliforms and E. coli was assessed, although these results are not alarming (Table 31). It can be easily said that Dusheti Region is in a much better situation than the rest of the locations studied by us on the territory of Eastern Georgia.

And finally, based on the results we can conclude that the uncontrolled landfill sites in some regions of Eastern Georgia play a significant negative role in the process of polluting the surrounding areas with certain components. First of all, there are unsanitary conditions in the mentioned locations with dramatically increased amounts of intestinal bacteria in the ecosystems. In the soil and surface water samples, we assessed the increased concentration of toxic elements such as Pb and Cd. Very often, some biogenic elements exceed their Maximum Allowable Concentrations in the analyzed samples. There is a probability that the current situation may have a significant negative impact on both human and domestic animal health as they spend long periods of time or live in such locations.

WESTERN GEORGIA

Imereti Region

In Imereti Region, we performed hydrochemical, physicochemical, and microbiological analyses of the samples collected from the surrounding areas of the illegal landfill sites in Terjola, Vani, and Khoni Municipalities.

The results are shown in Tables 32–35 and Graphs 27–29.

Table 32. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Imereti Region

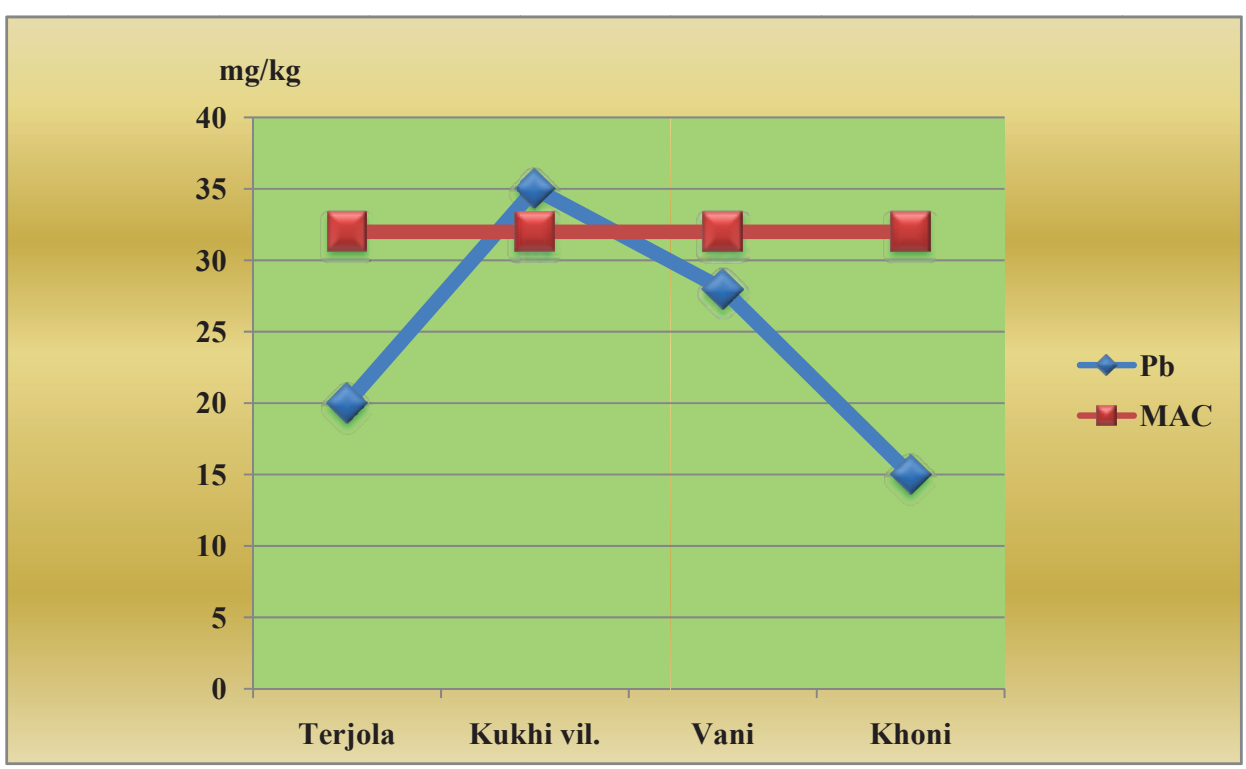
Sampling location	Sampling time	Coordinates	Alti-tude (m.a.s.l.)	pH	HCO_3^- mg/kg	NO_2^- mgN/kg	NO_3^- mgN/kg	PO_4^{3-} mg/kg	NH_4^+ mgN/kg	SO_4^{2-} mg/kg
Terjola, Gvaneti village	07.05.2014	332278 4669344	86	6.7	380	**0.25**	**20**	**16**	13.5	23.5
Vani, the surrounding area of the Chishura River	06.05.2014	294043 4662123	58	6.58	315	0.05	15	**24**	23	105
Khoni, Kukhi village	05.05.2014	288934 4686341	101	6.64	340	0.005	32	6.0	25	48.5
Khoni (background)	05.05.2014	287601 4689091	126	6.52	305	0.005	5.5	3.0	17	18

Table 33. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Imereti Region

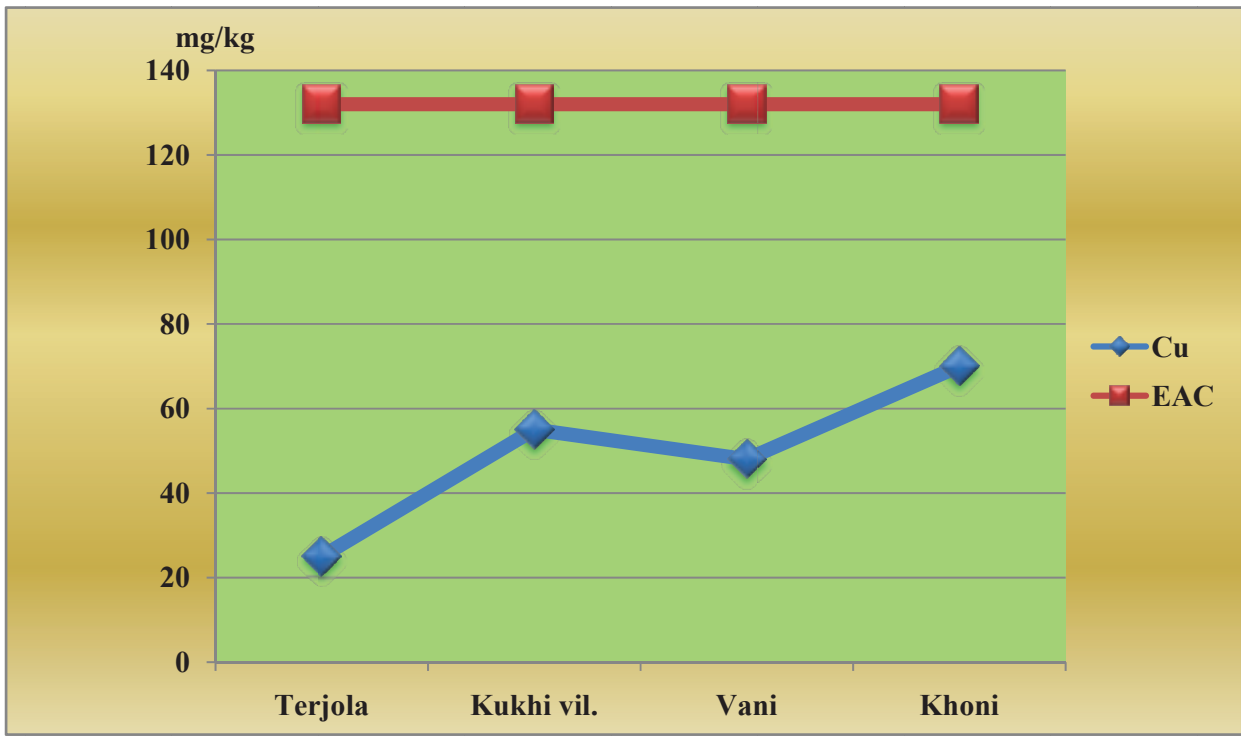
Sampling location	Sampling time	Coordinates	Total coliform titer	E. coli titer
Terjola, Gvaneti village	07.05.2014	332278 4669344	0.01	0.01
Vani, the surrounding area of the Chishura River	06.05.2014	294043 4662123	0.1	0.1
Khoni, Kukhi village	05.05.2014	288934 4686341	0.001	0.001
Khoni (background)	05.05.2014	287601 4689091	0.01	0.01

Table 34. The heavy metal (Cu, Zn, Pb, Cd) concentration in the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Imereti Region

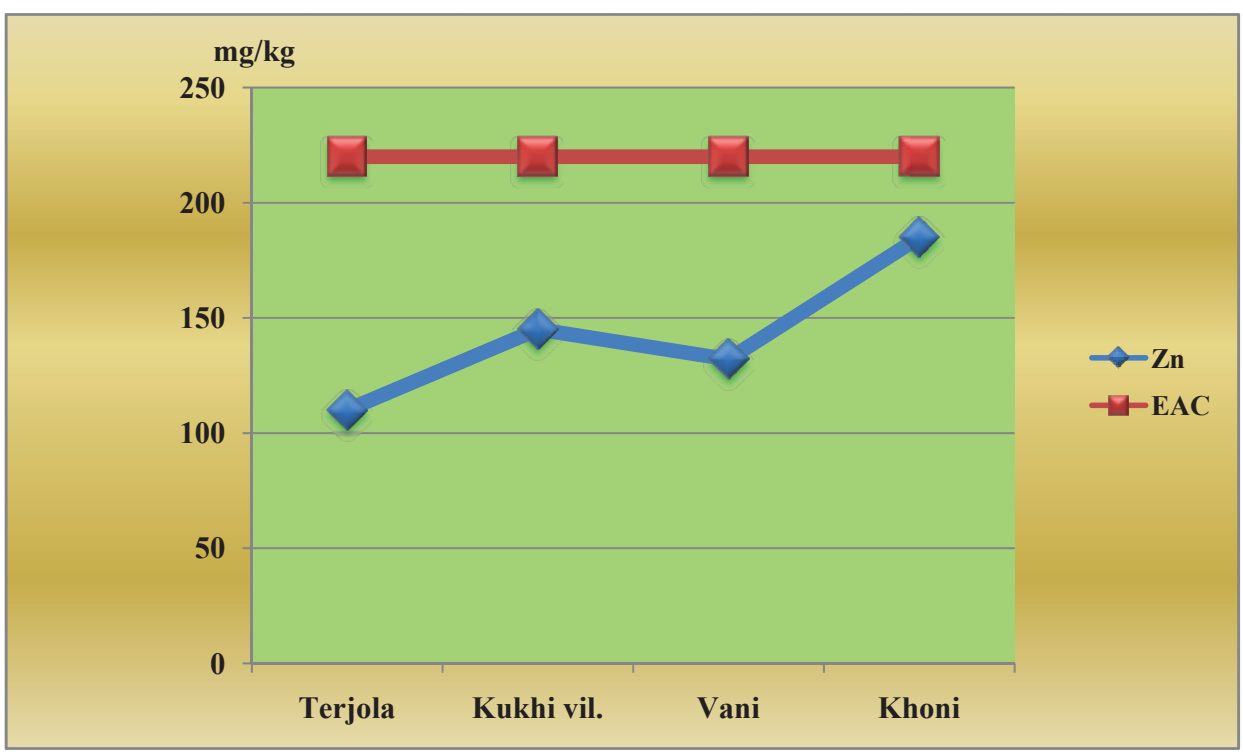
Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Cu, ppm	Zn, ppm	Pb, ppm	Cd, ppm
Terjola, Gvaneti village	07.05.2014	332278 4669344	86	25	110	20	<2. 5
Vani, the surrounding area of the Chishura River	06.05.2014	294043 4662123	58	48	132	28	<2.5
Khoni, Kukhi village	05.05.2014	288934 4686341	101	55	145	35	<2.5
Khoni (background)	05.05.2014	287601 4689091	126	70	185	15	<2.5
Maximum Allowable Concentration (MAC)						32	
Estimated Allowable Concentration (EAC)				132	220	130	2.0



Graph 27. The lead concentration in the soil samples collected in Imereti Region



Graph 28. The copper concentration in the soil samples collected in Imereti Region



Graph 29. The zinc concentration in the soil samples collected in Imereti Region

Table 35. The results of hydrochemical and microbiological analyses of the water samples collected from the Chishura River (2014)

№	Parameters	Units	Measurement results
1	pH		7.95
2	Hydrogen carbonate	mg/l	78.08
3	Nitrate	mgN/l	0.193
4	Nitrite	mgN/l	0.351
5	Ammonium	mgN/l	0.264
6	Phosphate	mg/l	0.03
7	Sulfate	mg/l	31.886
8	Total coliforms	per 1 liter	11200
9	E. coli	per 1 liter	4500

In spite of the fact that in the soil samples collected in Vani and Kukhi village, the lead concentration is more or less higher than the Maximum Allowable Concentration (Graph 27), using the results we can conclude that the soil samples from the surrounding areas of the landfill sites in Imereti Region are less polluted with heavy metals than the similar samples collected in Eastern Georgia. At the same time, hydrochemical and microbiological analyses showed that the Chishura River could be categorized as polluted (Table 35).

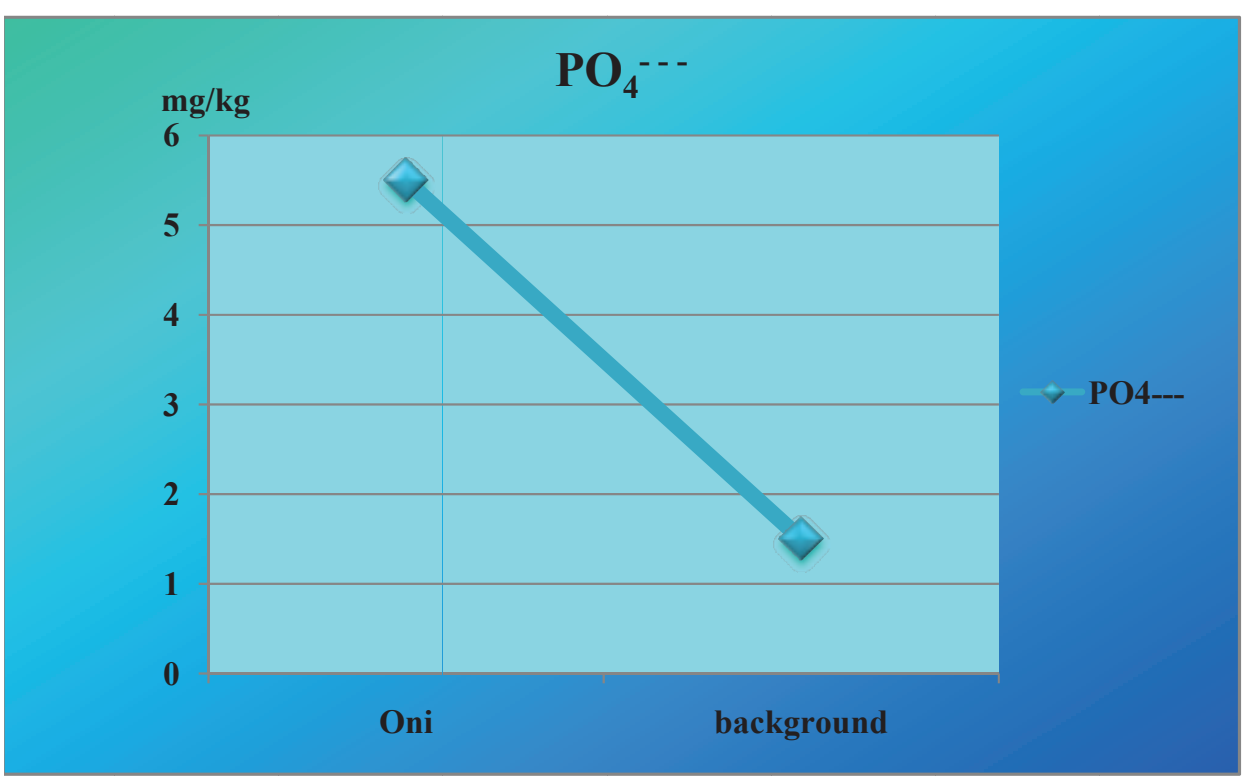
Racha-Lechkhumi and Kvemo Svaneti Region

The next location of the fieldworks was Racha-Lechkhumi and Kvemo Svaneti Region. Namely, we selected the surrounding areas of the uncontrolled landfill sites in Oni and Tsageri as well as one background location for each research spot. The results of hydrochemical and microbiological analyses of the collected samples are shown in Tables 36–40 and Graphs 30–35.

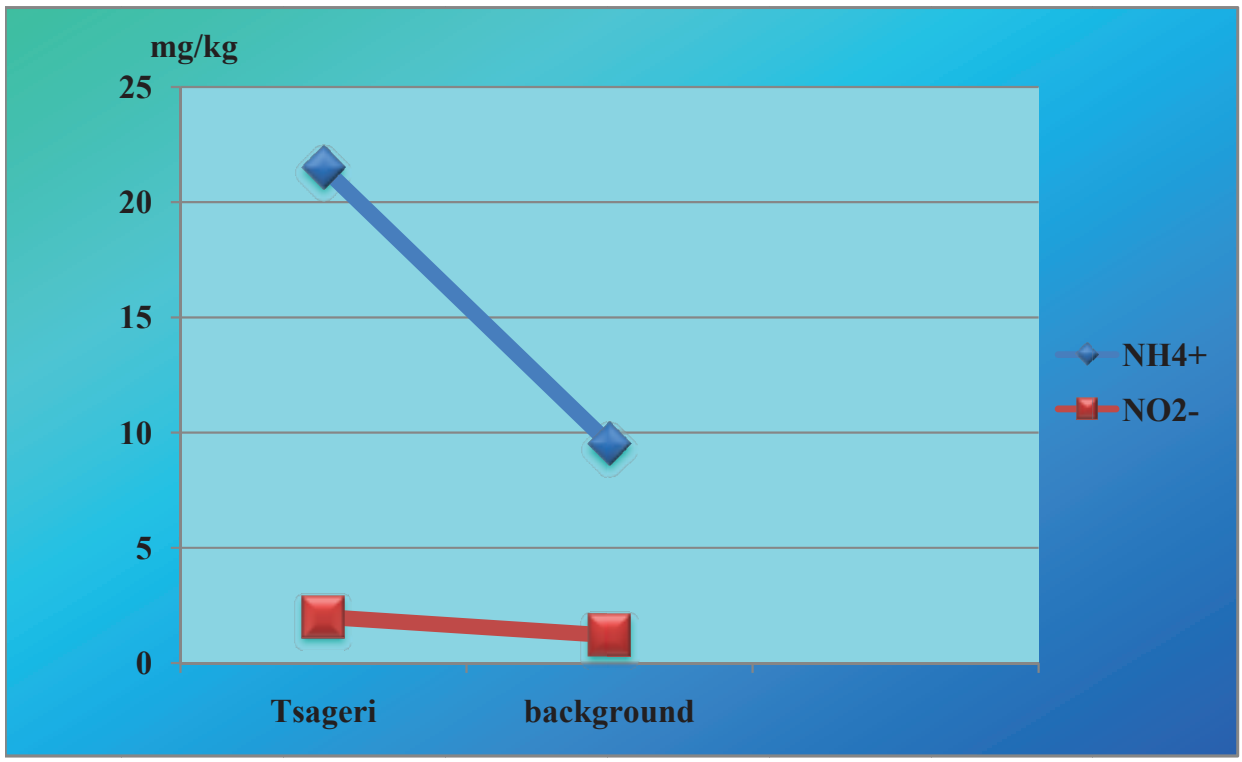
The results of hydrochemical analysis showed that the soil samples collected from these two areas in Racha Region are not significantly polluted with biogenic elements. For example, in the samples collected in Oni, the phosphate ion concentration is 3.5 times higher than the background values, while in the samples collected in Tsageri, the ammonium ion concentration is only 2.25 times higher than in the background samples (Table 36, Graphs 30–31).

Table 36. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Racha-Lechkhumi and Kvemo Svaneti Region

Sampling location	Sampling time	Coordinates	Alti-tude (m.a.s.l.)	pH	HCO_3^- mg/kg	NO_2^- mgN/kg	NO_3^- mgN/kg	PO_4^{3-} mg/kg	NH_4^+ mgN/kg	SO_4^{2-} mg/kg
Oni, the surrounding area of the Jojora River	22.07.2014	371054 4714687	790	7.68	408.5	1.5	10.0	5.5	7.0	119.0
Oni (back ground)	22.07.2014	371667 4714639	798	7.62	371	4.0	10.0	1.5	13.0	65.0
Tsageri area, Chalistavi village	21.07.2014	314415 4721326	466	7.8	255	2.0	10.0	3.0	21.5	95.0
Tsageri (back ground)	21.07.2014	317864 4725177	528	7.98	365	1.2	15.0	2.5	9.5	37.5



Graph 30. The phosphate ion concentration in the soil samples collected in Racha Region



Graph 31. The ammonium and nitrate ion concentration in the soil samples collected in Racha Region

The results of microbiological analysis are shown in Table 37. As we can see, the soil samples can be categorized as heavily polluted in this case. Except for one background location, which is located in the surrounding area of Tsageri Municipality.

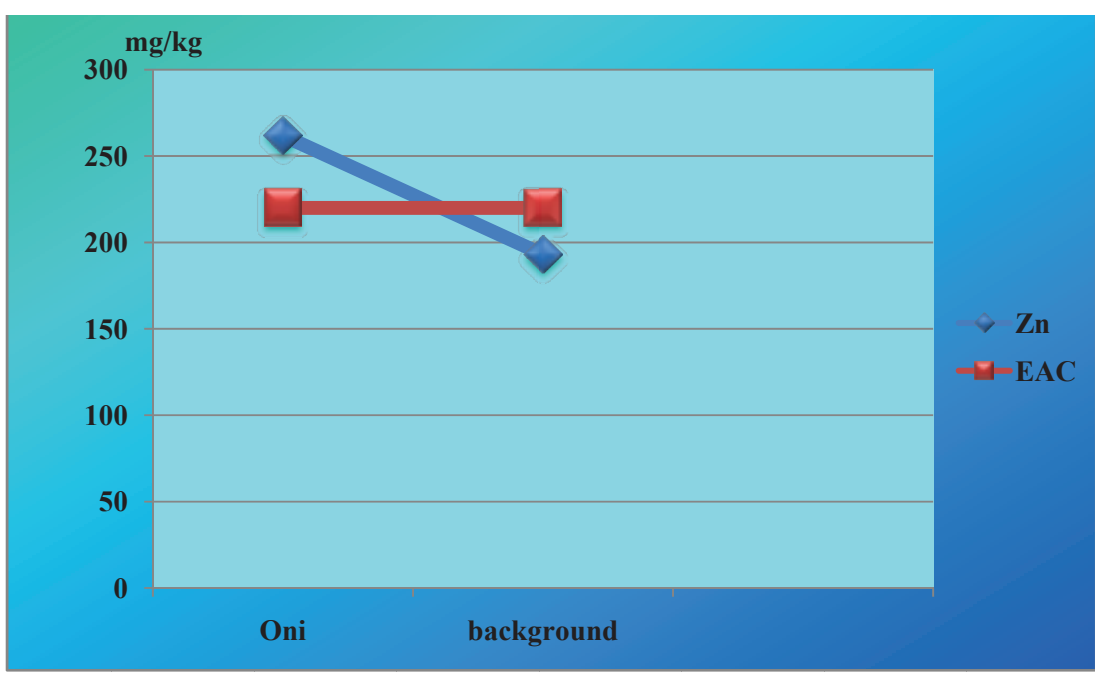
Table 37. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Racha-Lechkhumi and Kvemo Svaneti Region

Sampling location	Sampling time	Coordinates	Altitude (m)	Total coliform titer	E. coli titer
Oni, the surrounding area of the Jojora River	22.07.2014	371054 4714687	790	0.0001	0.0001
Oni (background)	22.07.2014	371667 4714639	798	0.0001	0.0001
Tsageri area, Chalistavi village	21.07.2014	314415 4721326	466	0.0001	0.0001
Tsageri (background)	21.07.2014	317864 4725177	528	0.01	0.01

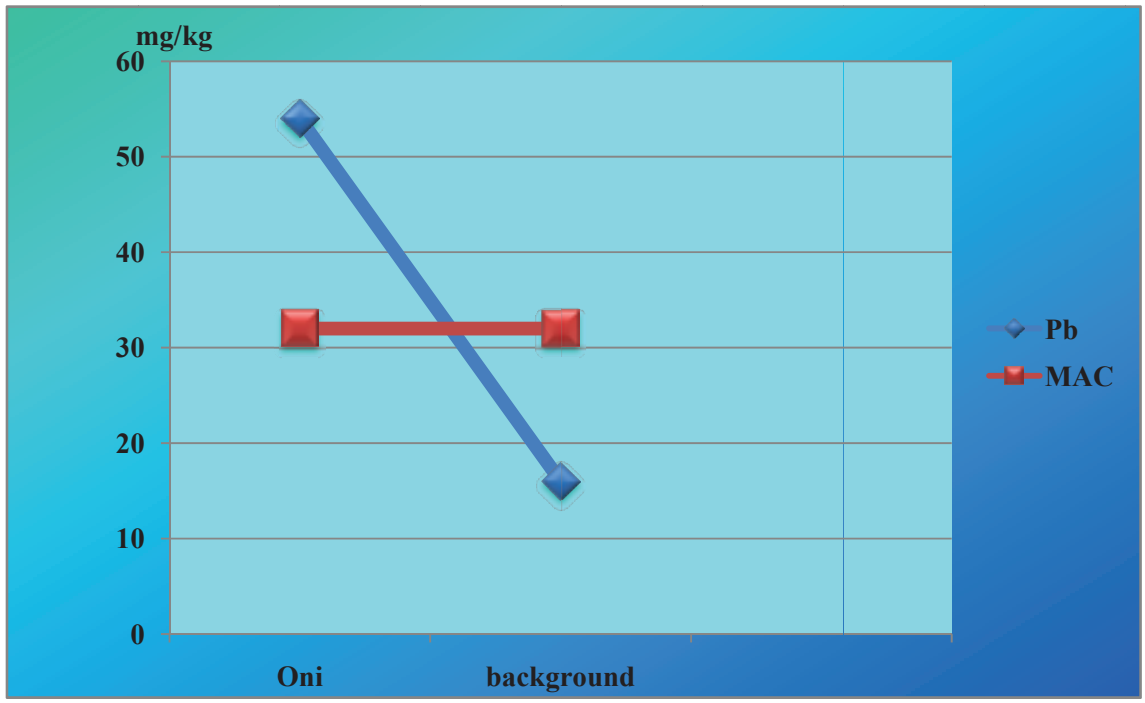
We performed another analysis of the samples in order to assess the heavy metal concentration. The results are shown in Table 38 and Graphs 32–33.

Table 38. The heavy metal (Cu, Zn, Pb, Cd) concentration in the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Racha-Lechkhumi and Kvemo Svaneti Region

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Cu, ppm	Zn, ppm	Pb, ppm	Cd, ppm
Oni, the surrounding area of the Jojora River	22.07.2014	371054 4714687	790	63	262	54	<2.5
Oni (background)	22.07.2014	371667 4714639	798	54	193	16	<2.5
Tsageri area, Chalistavi village	21.07.2014	314415 4721326	466	53	108	21	<2.5
Tsageri (background)	21.07.2014	317864 4725177	528	31	89	24	<2.5
Maximum Allowable Concentration (MAC)						32	
Estimated Allowable Concentration (EAC)				132	220	130	2.0



Graph 32. The zinc concentration in the soil samples collected in Racha Region



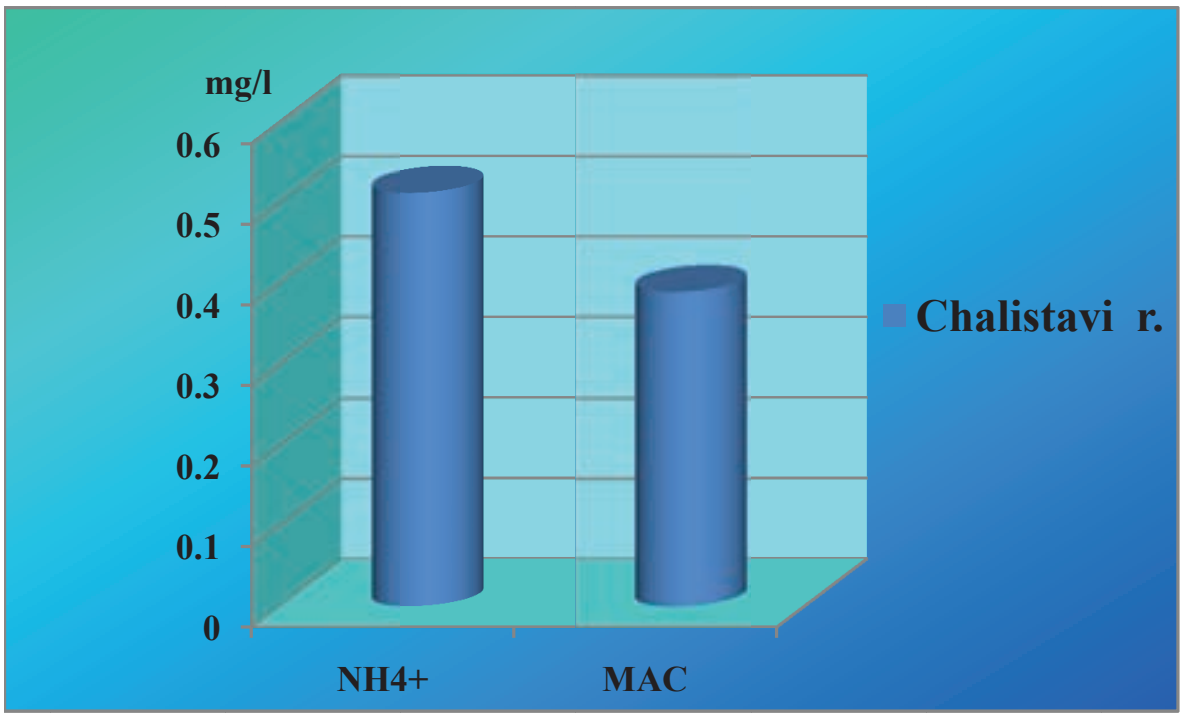
Graph 33. The lead concentration in the soil samples collected in Racha Region

It is obvious that in the samples collected in Oni, the zinc and lead concentrations are not only higher than the background levels but also exceed both the Maximum Allowable Concentration (MAC) and Estimated Allowable Concentration (EAC). As for the soil samples collected in Tsageri, the copper and zinc concentrations are insignificantly higher than the corresponding background values.

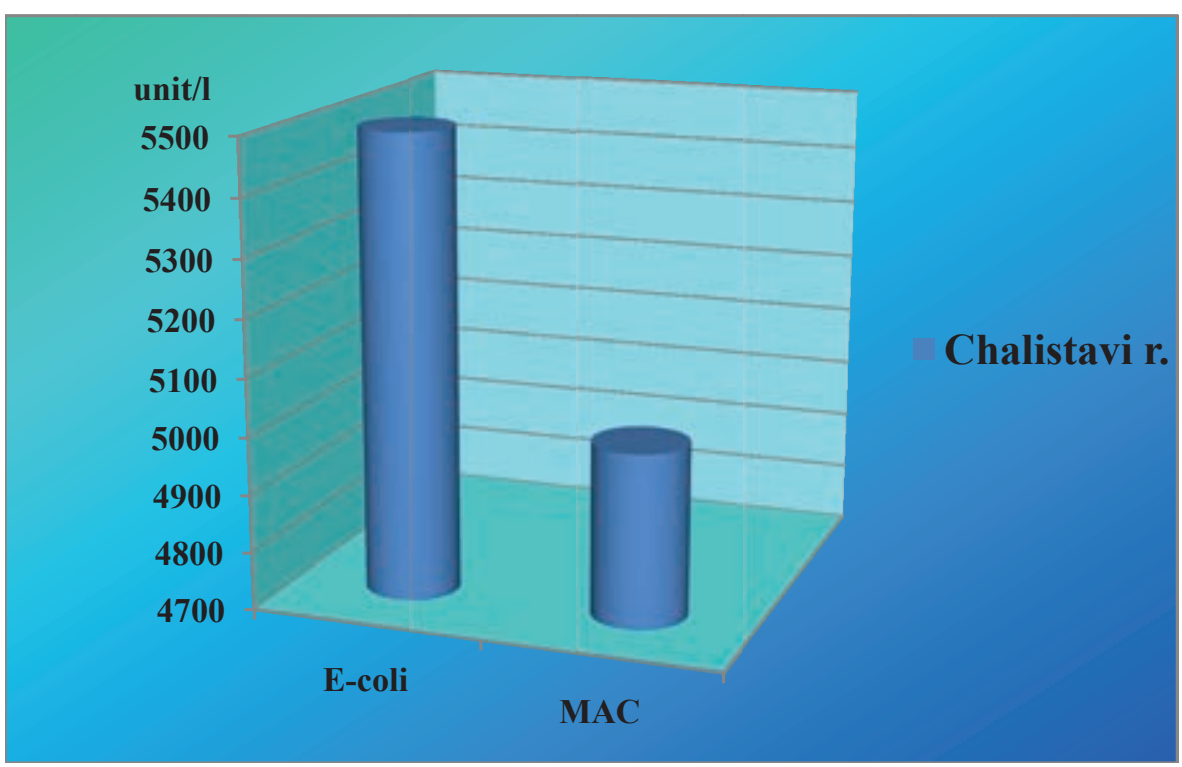
In addition, we performed hydrochemical and microbiological analyses of both the soil samples collected in the Racha Region and the water samples from the Chalistavi River. Physicochemical properties were determined in the field. The results are shown in Tables 39–40 and Graphs 34–35.

Table 39. Physicochemical properties of the water samples collected from the Chalistavi River (Tsageri area) (2014)

Sampling location	Sampling time	Coordinates	pH	Conductivity µS/cm	Salinity	Do, mg/l	T,°C
Tsageri area, Chalistavi village	21.07.2014	314415 4721326	8.6	99.5	0.1	4.5	17.6



Graph 34. The ammonium ion concentration of the water samples collected from the Chalistavi River



Graph 35. The E. coli concentration of the water samples collected from the Chalistavi River

Table 40. The results of hydrochemical and microbiological analyses of the water samples collected from the Chalistavi River (Tsageri area, Chalistavi village)

№	Parameters	Units	Measurement results
1	pH		8.6
2	Hydrogen carbonate	mg/l	126.88
3	Nitrate	mgN/l	0.184
4	Nitrite	mgN/l	0.535
5	Ammonium	mgN/l	0.513
6	Phosphate	mg/l	0.095
7	Sulfate	mg/l	54.88
8	Total coliforms	per 1 liter	16000
9	E. coli	per 1 liter	5500

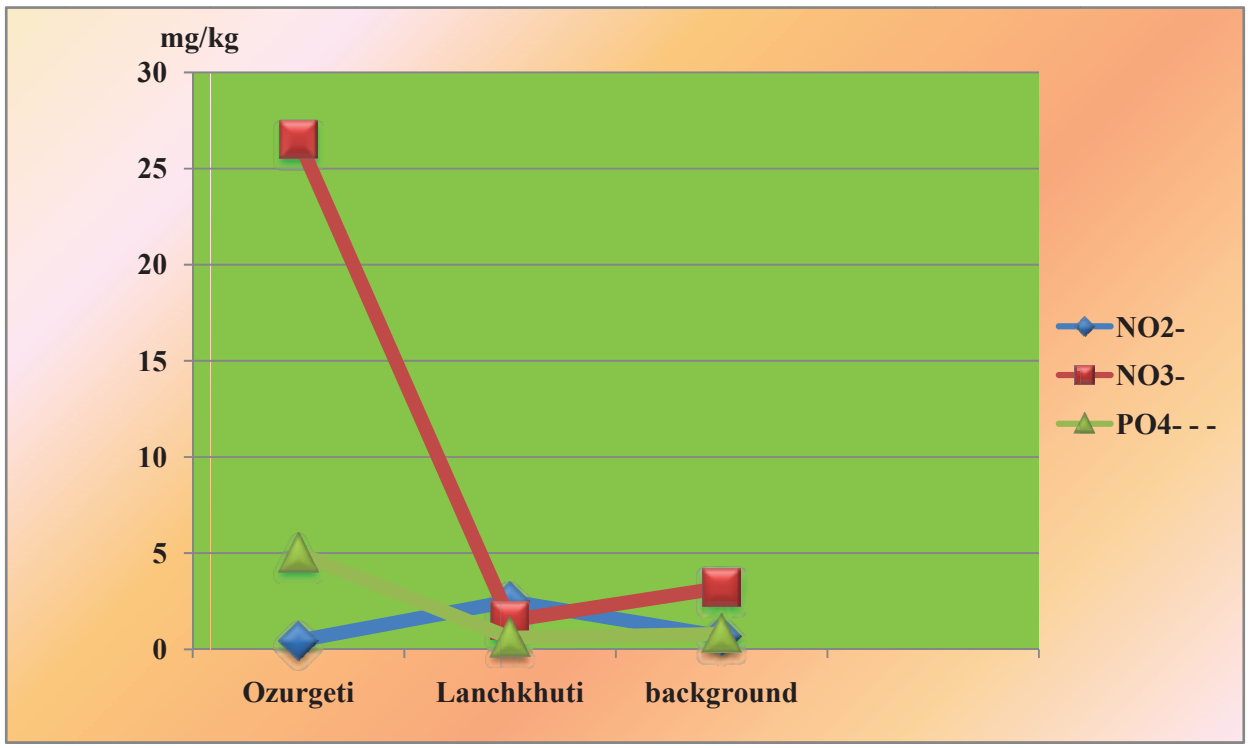
It can be said that just like in Imereti Region, in Racha (Oni, Tsageri) too the surrounding areas of the illegal landfill sites are less polluted than the majority of similar locations in Eastern Georgia. From a microbiological viewpoint, however, the results show us that the collected samples of both soil and water are polluted with active intestinal bacteria such as E. coli and total coliforms (Graph 35).

Guria Region

In Guria Region, the research samples were collected in Ozurgeti and Lanchkhuti Municipalities. The background location was chosen in the same area but far from the landfill sites. The water samples from the Bzhuzha (Ozurgeti) and Shuti (Lanchkhuti) Rivers were collected and analyzed. The results are shown in Tables 41–45 and Graphs 36–40.

Table 41. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Guria Region

Sampling location	Sampling time	Coordinates	Alti-tude (m.a.s.l.)	pH	HCO_3^- mg/kg	NO_2^- mgN/kg	NO_3^- mgN/kg	PO_4^{3-} mg/kg	NH_4^+ mgN/kg	SO_4^{2-} mg/kg
Ozurgeti, the embankment area	06.08.2014	748027 4645341	63	6.8	210	0.45	26.5	5.0	3.0	110
Lanchkhuti, Guliani village (Shuti gorge)	06.08.2014	741982 4656693	56	6.7	317.2	2.5	1.5	0.6	3.5	330
Background	06.08.2014	742358 4655469	61	7.0	220	0.68	3.2	0.8	2.0	125



Graph 36. The biogenic element concentration in the soil samples collected in Guria Region

Table 42. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Guria Region

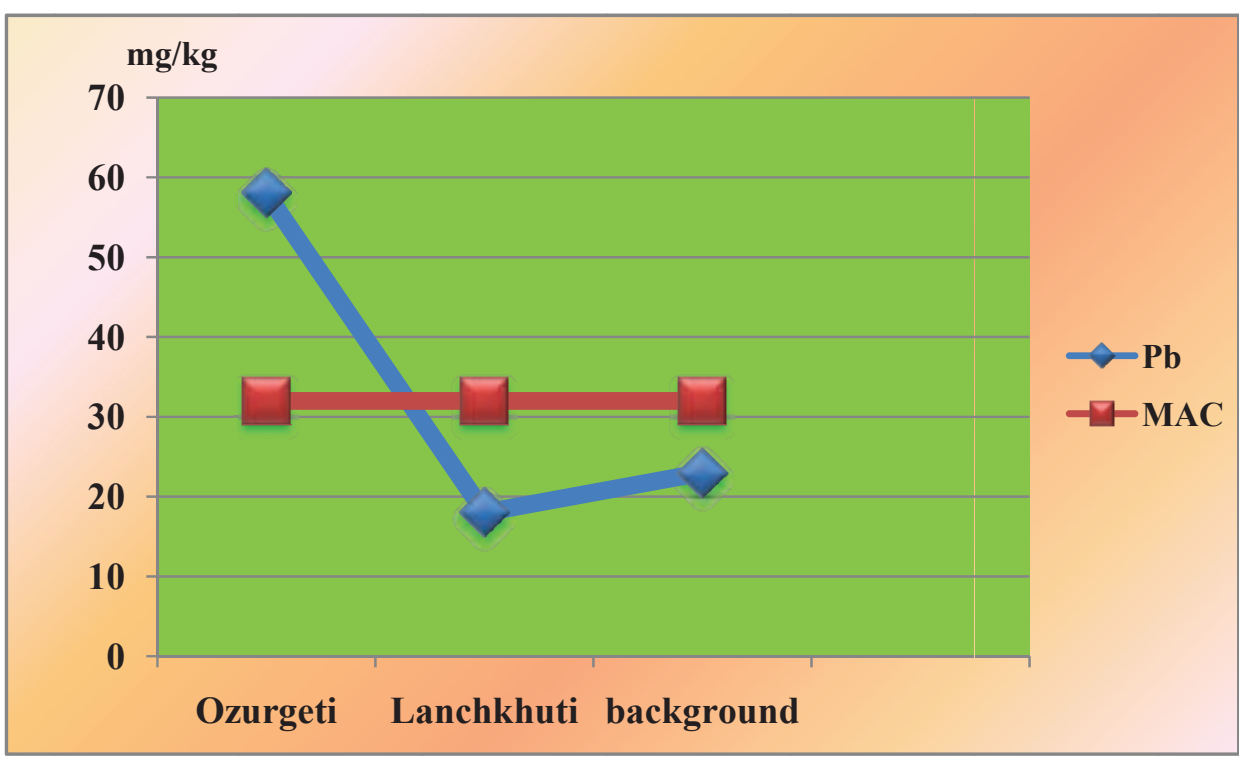
Sampling location	Sampling time	Coordinates	Altitude (m)	Total coliform titer	E. coli titer
Ozurgeti, the embankment area	06.08.2014	748027 4645341	63	0.001	0.001
Lanchkhuti, Guliani village (Shuti gorge)	06.08.2014	741982 4656693	56	0.1	0.1
Background	06.08.2014	742358 4655469	61	0.1	0.1

It is obvious that the research samples collected in Ozurgeti are polluted with nitrate ions (NO_3^-) and their concentration is 8.5 times higher than the background values, while the PO_4^{3} concentration is 6 times higher. Based on the results of microbiological analysis, the samples can be categorized as polluted (Tables 41–42, Graph 36).

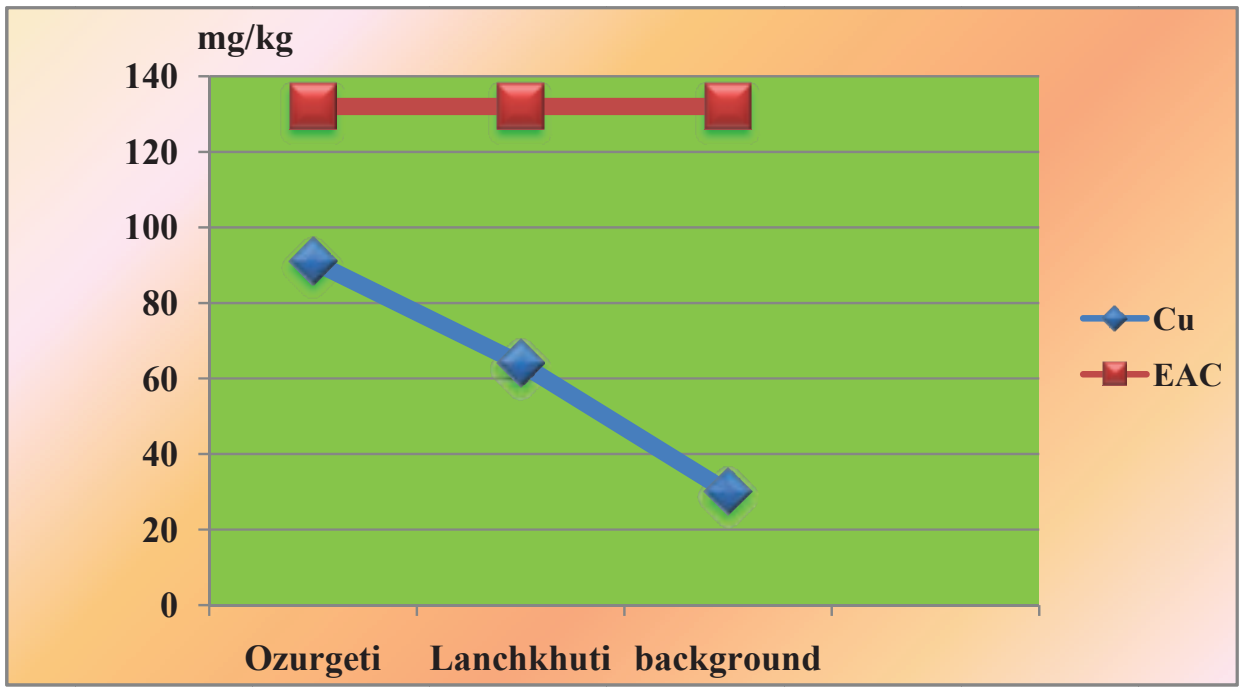
The heavy metal concentration was assessed in the abovementioned samples as well. The results are shown in Table 43 and Graphs 37–39.

Table 43. The heavy metal (Cu, Zn, Pb, Cd) concentration in the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Guria Region

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Cu, ppm	Zn, ppm	Pb, ppm	Cd, ppm
Ozurgeti, the embankment area	06.08.2014	748027 4645341	63	91.0	242.0	58	<2.5
Lanchkhuti, Guliani village (Shuti gorge)	06.08.2014	741982 4656693	56	64.0	72.0	18.0	<2.5
Background	06.08.2014	742358 4655469	61	30	64	23	<2.5
Maximum Allowable Concentration (MAC)						32	
Estimated Allowable Concentration (EAC)				132	220	130	2.0



Graph 37. The lead concentration in the soil samples collected in Guria Region



Graph 38. The copper concentration in the soil samples collected in Guria Region

Graph 39. The zinc concentration in the soil samples collected in Guria Region

As we can see, the zinc concentration in the soil samples is not only higher than the background values but it also exceeds the Estimated Allowable Concentration (EAC). In addition, the concentration of toxic metals such as lead turned out to be higher than the Maximum Allowable Concentration. It should be noted that in the soil samples collected in Imereti, Racha, and Guria Regions, we have not even once assessed the cadmium concentration (Graphs 37–39).

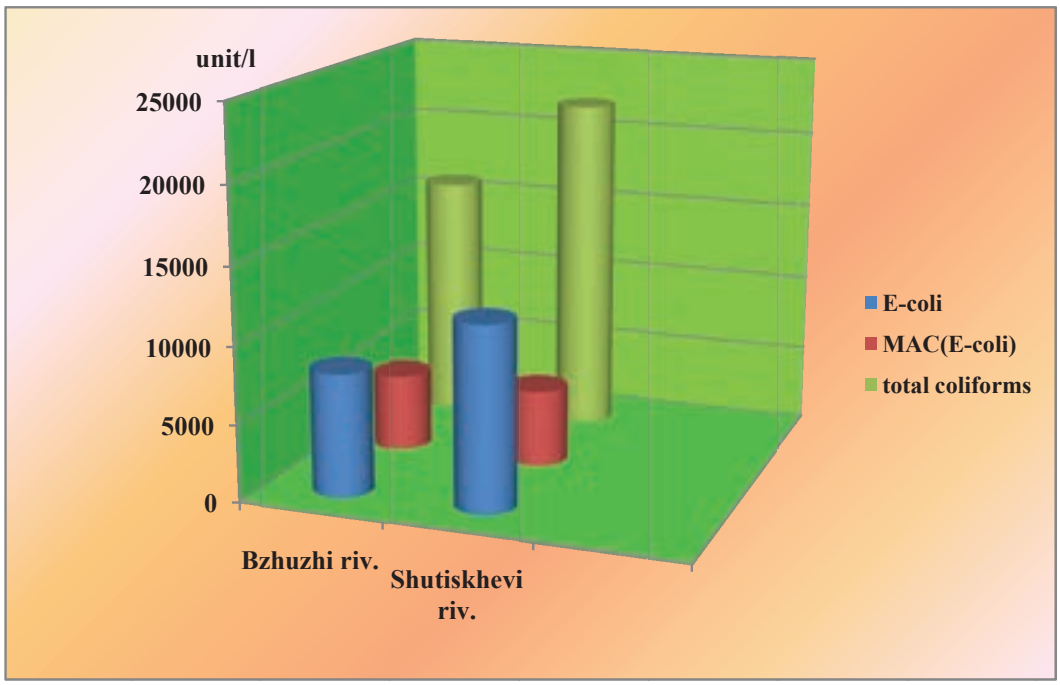
In the water samples collected from the rivers in the region (The Bzhuzha, and Shuti Rivers) we have assessed a certain amount of total coliforms and E. coli. Although, their existence in the surface waters in such amounts is not alarming (Tables 44–45, Graph 40).

Table 44. The results of hydrochemical and microbiological analyses of the water samples collected from the Bzhuzha River (Ozurgeti)

№	Parameters	Units	Measurement results
1	pH		7.8
2	Hydrogen carbonate	mg/l	68.2
3	Nitrate	mgN/l	0.199
4	Nitrite	mgN/l	0.001
5	Ammonium	mgN/l	0.062
6	Phosphate	mg/l	0.077
7	Sulfate	mg/l	7.383
8	Total coliforms	per 1 liter	16000
9	E. coli	per 1 liter	8000

Table 45. The results of hydrochemical and microbiological analyses of the water samples collected from the Shuti River (Lanchkhuti area, Guliani village)

№	Parameters	Units	Measurement results
1	pH	M	7.5
2	Hydrogen carbonate	mg/l	134.2
3	Nitrate	mgN/l	0.004
4	Nitrite	mgN/l	0.04
5	Ammonium	mgN/l	0.101
6	Phosphate	mg/l	0.037
7	Sulfate	mg/l	102.3
8	Total coliforms	per 1 liter	22000
9	E. coli	per 1 liter	12000



Graph 40. The E- coli and total coliforms concentrations of the water samples collected from the Rivers Bzhuzha and Shuti

Adjara Region

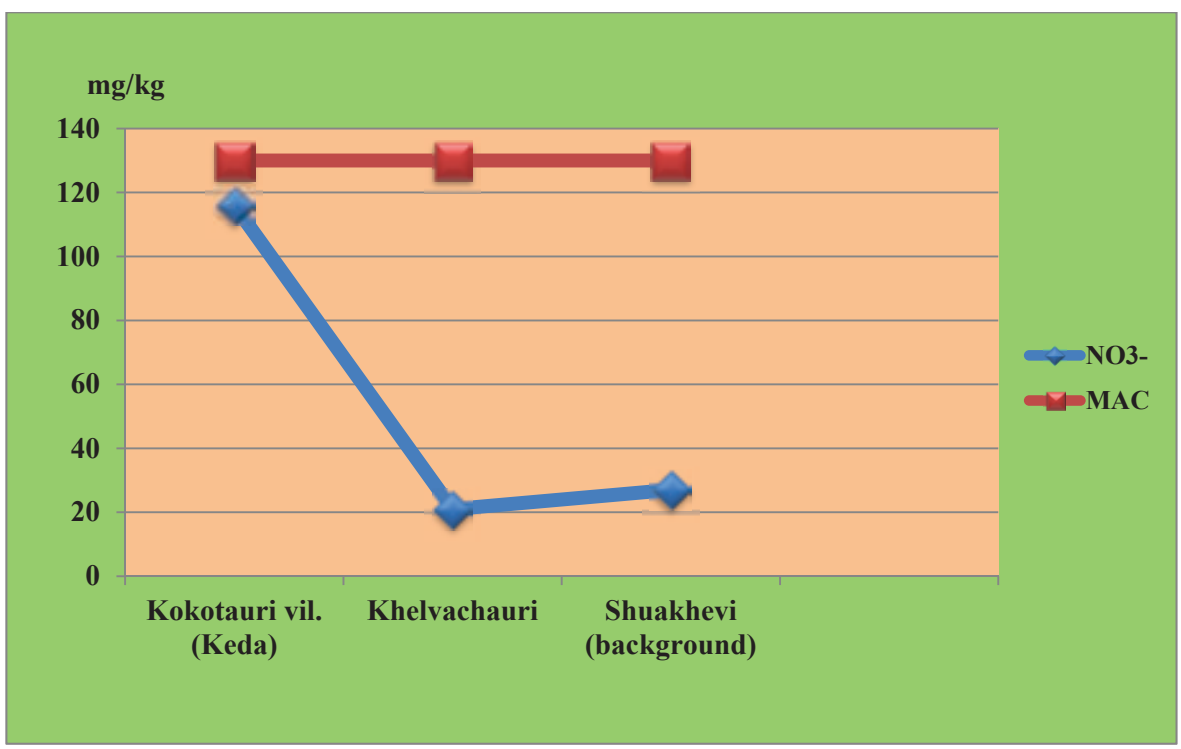
The analysis samples were also collected in Adjara Region. Namely, in Keda Municipality (Kokotauri village); Khelvachauri, the right bank of the Chorokhi River; and in Shuakhevi (the Municipality yard area). Using the collected samples, were performed hydrochemical and microbiological analyses. The results are shown in Tables 46–49 and Graphs 41–44.

Table 46. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Adjara Region

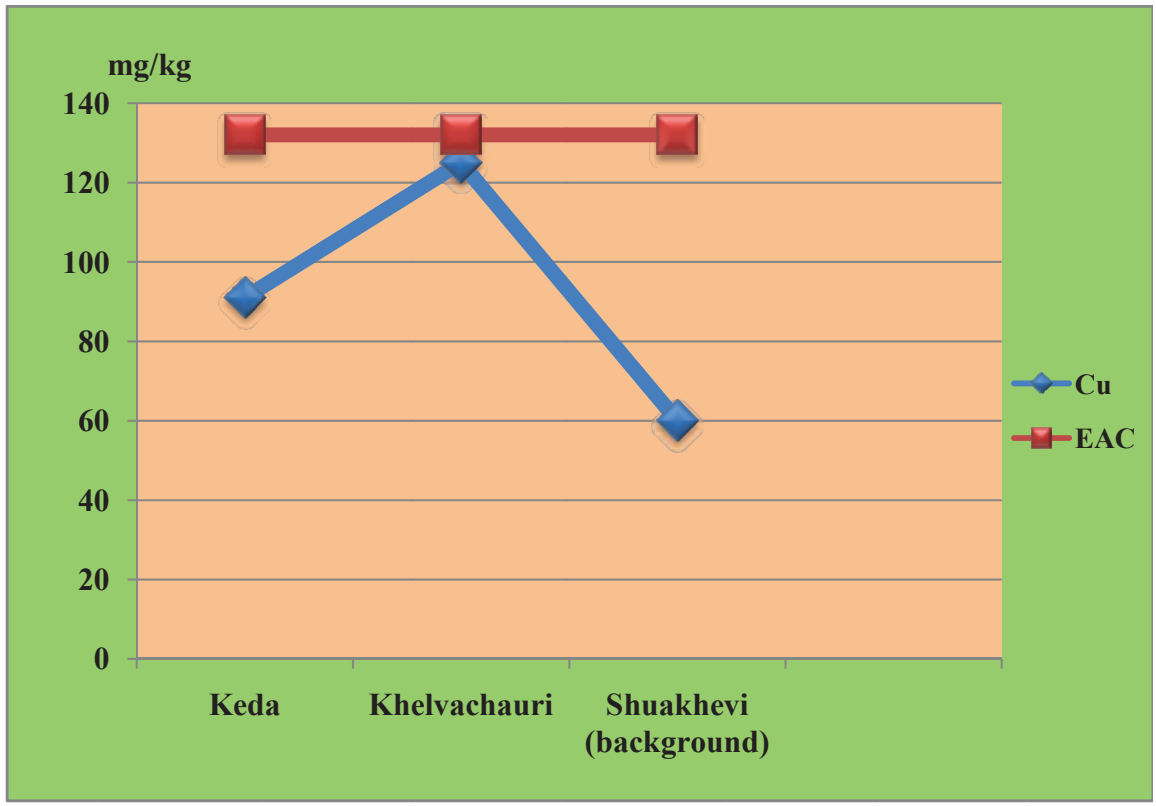
Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	pH	HCO_3^- mg/kg	NO_2^- mgN/kg	NO_3^- mgN/kg	PO_4^{3-} mg/kg	NH_4^+ mgN/kg	SO_4^{2-} mg/kg
Keda District, Kokotauri village	19.08.2014	256566 4613863	317	6.58	510	3.0	116.0	0.5	4.5	65
Khelvachauri, the right bank of the Chorokhi River	19.08.2014	721707 4605703	25	6.78	315	1.8	21	16	6.0	85
Shuakhevi, the Municipality area (background)	19.08.2014	265924 4612079	439	7.2	180	12.5	2.3	27.0	10.0	65

Table 47. The heavy metal (Cu, Zn, Pb, Cd) concentration in the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Adjara Region

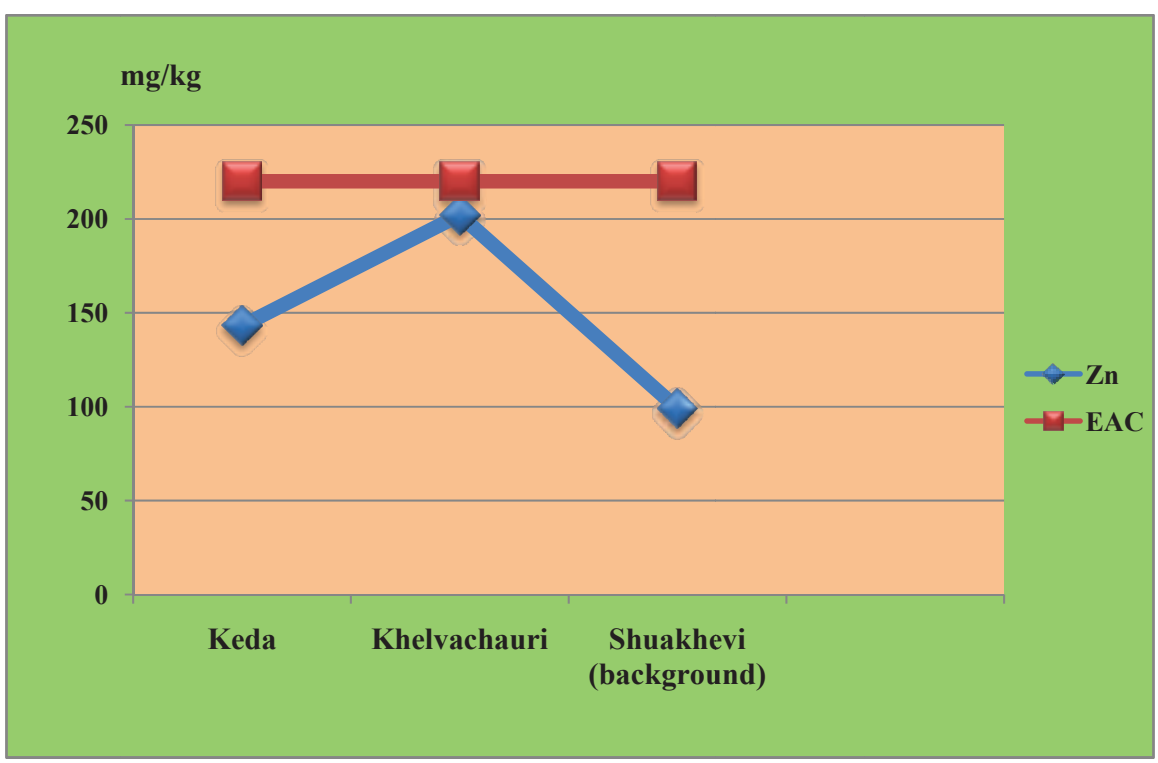
Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Cu, ppm	Zn, ppm	Pb, ppm	Cd, ppm
Keda District, Kokotauri village	19.08.2014	256566 4613863	317	91.0	143.0	38.0	<2.5
Khelvachauri, the right bank of the Chorokhi	19.08.2014	721707 4605703	25	125.0	202	141	<2.5
Shuakhevi, the Municipality area (background)	19.08.2014	265924 4612079	439	60.0	99.0	18.0	<2.5
Maximum Allowable Concentration (MAC)						32	2.0
Estimated Allowable Concentration (EAC)				132	220	130	2.0



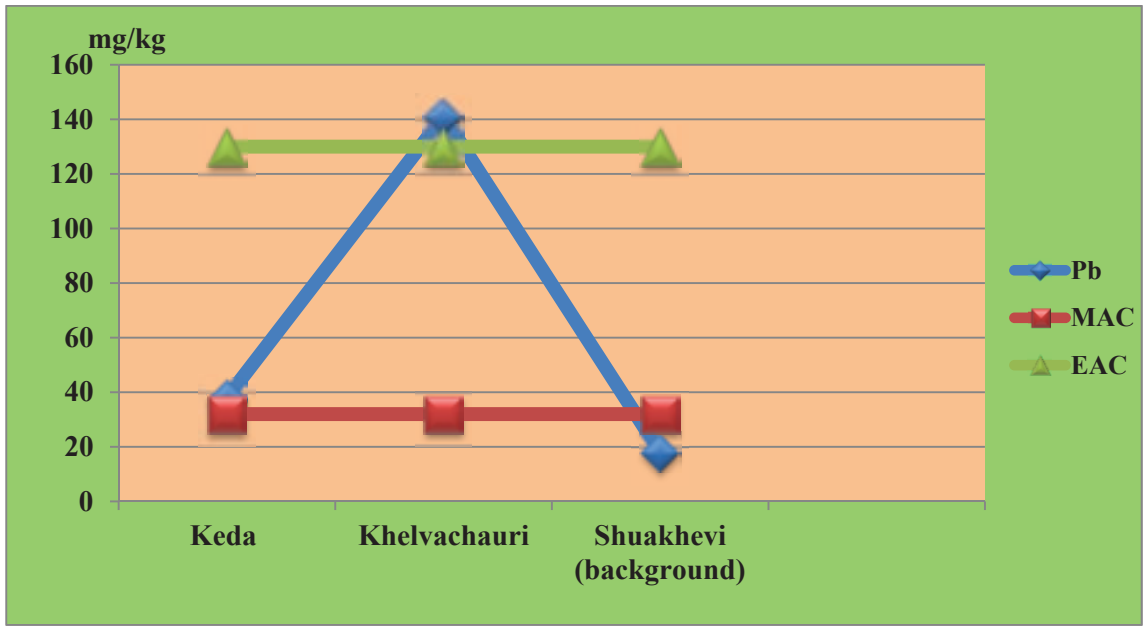
Graph 41. The nitrate ion concentration in the soil samples collected in Adjara Region



Graph 42. The copper concentration in the soil samples collected in Adjara Region



Graph 43. The zinc concentration in the soil samples collected in Adjara Region



Graph 44. The lead concentration in the soil samples collected in Adjara Region

Based on Graphs 42–44, we can conclude that in Adjara Region, the soil samples collected from the surrounding areas of the uncontrolled landfill site in Khelvachauri is notable for the high level of pollution with heavy metals. More precisely, the lead concentration exceeds both the Maximum Allowable Concentration and the background values, and is 4.3 and 8 times higher respectively. In the same soil samples collected in Khelvachauri, we have assessed the high copper and zinc concentrations. It should also be noted that from a microbiological viewpoint, the research samples collected in Keda and Khelvachauri turned out to be rather polluted (Table 48).

As for the Khevistskali River (Keda District), the results of hydrochemical and microbiological analyses are satisfactory (Table 49).

Table 48. The results of microbiological analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Adjara Region

Sampling location	Sampling time	Coordinates	Altitude (m)	Total coliform titer	E. coli titer
Keda District, Kokotauri village	19.08.2014	256566 4613863	317	0.0001	0.0001
Khelvachauri, the right bank of the Chorokhi	19.08.2014	721707 4605703	25	0.001	0.001
Shuakhevi, the Municipality territory (background)	19.08.2014	265924 4612079	439	>1.0	not found

Table 49. The results of hydrochemical and microbiological analyses of the water samples collected from the Khevistskali River (Keda District, Kokotauri village)

№	Parameters	Units	Measurement results
1	pH	M	8.1
2	Hydrogen carbonate	mg/l	119.56
3	Nitrate	mgN/l	0.468
4	Nitrite	mgN/l	0.001
5	Ammonium	mgN/l	0.078
6	Phosphate	mg/l	0.06
7	Sulfate	mg/l	29.78
8	Total coliforms	per 1 liter	7500
9	E. coli	per 1 liter	2000

Samegrelo-Zemo Svaneti Region

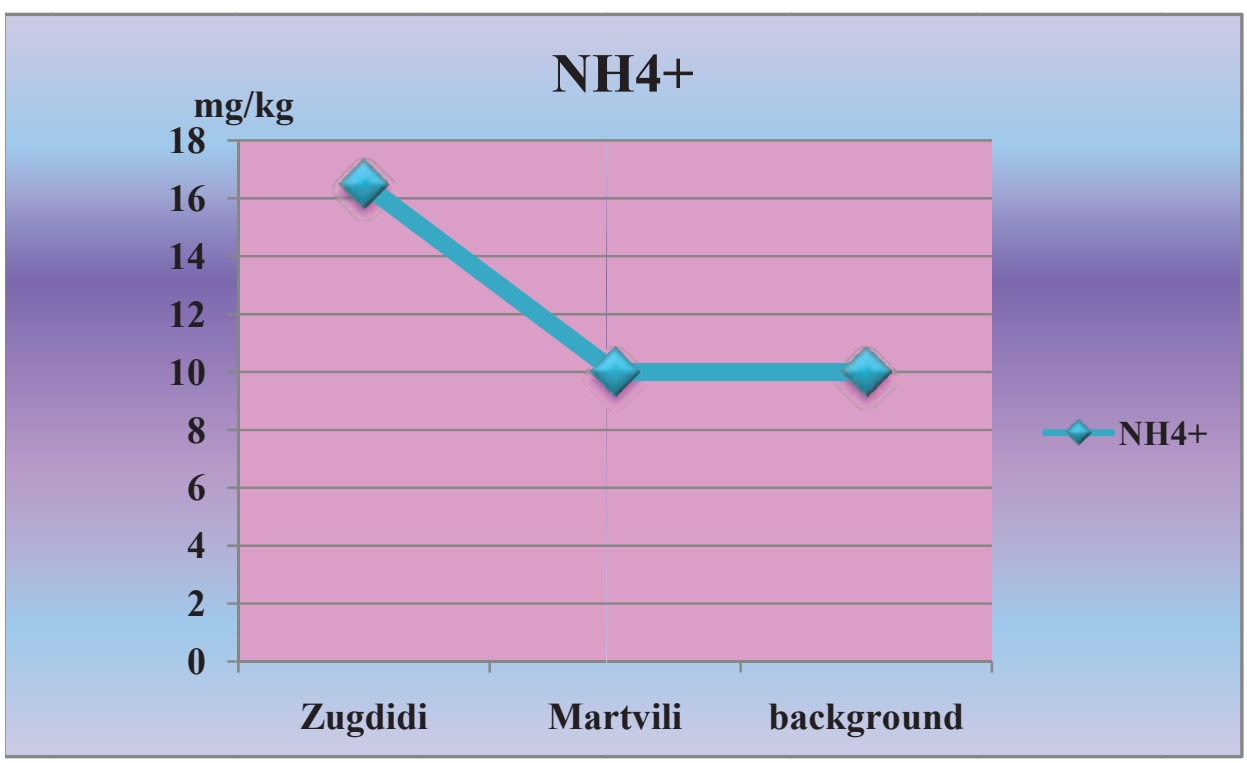
The analysis samples in Samegrelo-Zemo Svaneti Region were collected from the surrounding areas of the landfill sites in Zugdidi, Martvili, and Mestia. The results are shown in Tables 50–56 and Graphs 45–46.

Table 50. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Samegrelo-Zemo Svaneti Region

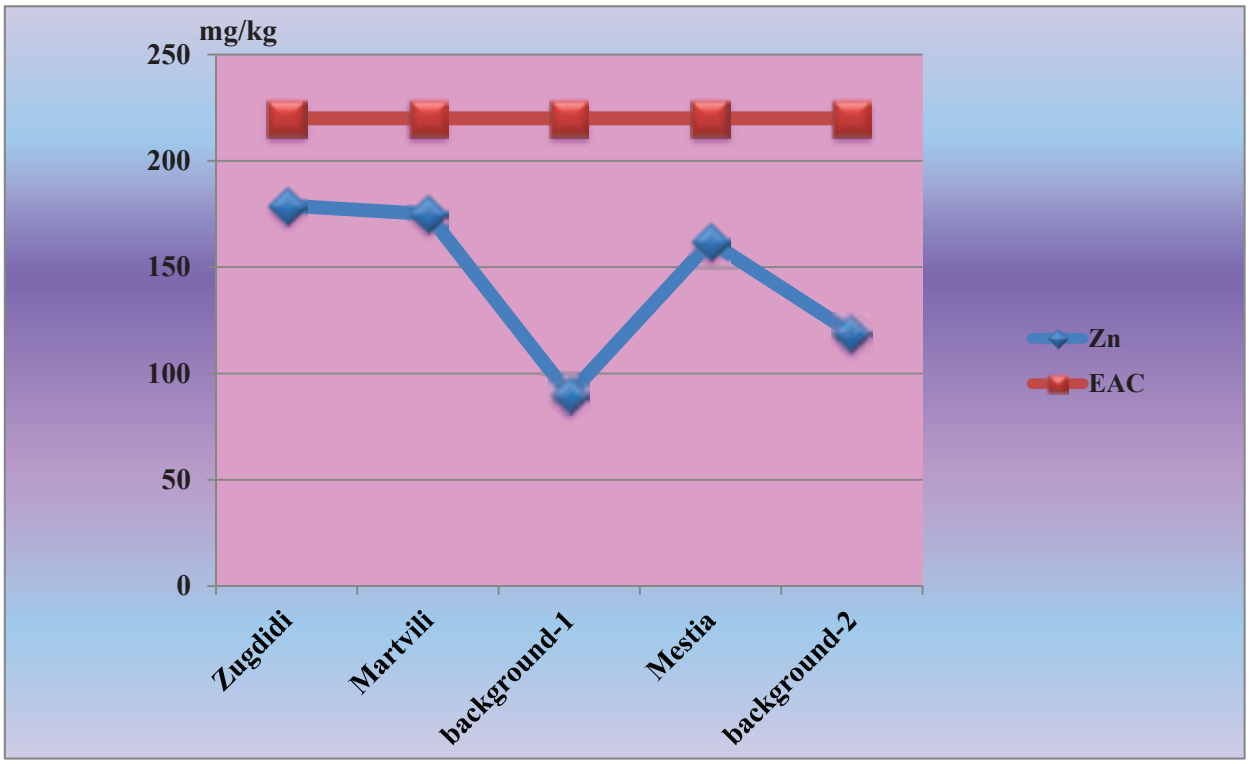
Sampling location	Sampling time	Coordinates	Alti-tude (m.a.s.l.)	pH	HCO_3^- mg/kg	NO_2^- mgN/kg	NO_3^- mgN/kg	PO_4^{3-} mg/kg	NH_4^+ mgN/kg	SO_4^{2-} mg/kg
Zugdidi, Khubulava Street	30.09.2014	733913 4708199	81	7.72	195	0.25	1.1	0.55	16.5	29.5
Zugdidi, Dadiani Palace yard (background)	30.09.2014	736186 4710633	130	7.69	355	0.35	13.5	1.0	10.0	39.0
Martvili, Nakharebao neighborhood	01.10.2014	282635 4697222	158	7.52	378	1.0	3.5	0.25	10.0	46.5
Mestia, Tuvshkveri area	04.10.2014	312801 4767864	1431	7.47	365	0.75	12.0	0.8	11.0	64.0
Mestia (background)	04.10.2014	312789 4767889	1437	7.42	488	35.5	26.5	0.005	17.5	33.5

Table 51. The heavy metal (Cu, Zn, Pb, Cd) concentration in the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Samegrelo-Zemo Svaneti Region

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Cu, ppm	Zn, ppm	Pb, ppm	Cd, ppm
Zugdidi, Khubulava Street	30.09.2014	733913 4708199	81	32	179	18	<2.5
Zugdidi, Dadiani Palace yard (background)	30.09.2014	736186 4710633	130	25	90	27	<2.5
Martvili, Nakharebao neighborhood	01.10.2014	282635 4697222	158	29	175	14	<2.5
Mestia, Tuvshkveri area	04.10.2014	312801 4767864	1431	75	162	14	<2.5
Mestia (background)	04.10.2014	312789 4767889	1437	58	119	20	<2.5
Maximum Allowable Concentration (MAC)						32	
Estimated Allowable Concentration (EAC)				132	220	130	2.0



Graph 45. The ammonium ion concentration in the soil samples collected in Samegrelo Region



Graph 46. The zinc concentration in the soil samples collected in Samegrelo-Zemo Svaneti Region

It can be said that none of the samples analyzed in the region were polluted with any form of the biogenic elements. In addition, the collected samples were not exceptional in terms of the heavy metal concentration. However, the results of microbiological analysis show that the surrounding area of the landfill site in Khubulava Street in Zugdidi is heavily polluted (Table 52).

Table 52. The results of microbiological analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Samegrelo-Zemo Svaneti Region

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Total coliform titer	E. coli titer
Zugdidi, Khubulava Street	30.09.2014	733913 4708199	81	**0.00001**	**0.00001**
Zugdidi, Dadiani Palace yard (background)	30.09.2014	736186 4710633	130	0.01	0.01
Martvili, Nakharebao neighborhood	01.10.2014	282635 4697222	158	0.001	0.001
Mestia, Tuvshkveri area	04.10.2014	312801 4767864	1431	0.001	0.001
Mestia (background)	04.10.2014	312789 4767889	1437	0.001	0.01

Table 53. The results of hydrochemical and microbiological analyses of the water samples collected from the Chkhoushi River (Zugdidi)

№	Parameters	Units	Measurement results
1	pH		8.04
2	Hydro carbonate	mg/l	48.2
3	Nitrate	mgN/l	0.978
4	Nitrite	mgN/l	0.001
5	Ammonium	mgN/l	0.474
6	Phosphate	mg/l	0.022
7	Sulfate	mg/l	5.282
8	Total coliforms	Per 1 liter	8000
9	E. coli	Per 1 liter	3500

Tables 53–56 show the results of hydrochemical, physicochemical, and microbiological analyses of the water samples collected from the Chkhoushi River (Zugdidi) and the Nakharebao landfill wastewater. Based on the results, we can conclude that the water samples are characterized by the low level of pollution.

Table 54. Physicochemical properties of the water samples collected from the Chkhoushi River (Zugdidi) (2014)

Sampling location	Sampling time	Coordinates	pH	conductivity, µS/cm	Salinity	Do, mg/l	T,°C
The Chkhoushi River (Zugdidi)	30.09.2014	733913 4708199	8.04	102.5	0.1	5.12	12.6

Table 55. The results of hydrochemical and microbiological analyses of the water samples collected from Nakharebao (Martvili) wastewater

№	Parameters	Units	Measurement results
1	pH		7.62
2	Hydrogen carbonate	mg/l	173.2
3	Nitrate	mgN/l	0.008
4	Nitrite	mgN/l	0.031
5	Ammonium	mgN/l	0.412
6	Phosphate	mg/l	0.054
7	Sulfate	mg/l	5.517
8	Total coliforms	Per 1 liter	14800
9	E. coli	Per 1 liter	5500

Table 56. Physicochemical properties of Nakharebao (Martvili) wastewater (2014)

Sampling location	Sampling time	Coordinates	pH	Conductivity µS/cm	Salinity	Do, mg/l	T,°C
Nakharebao neighborhood wastewater	01.10.2014	282635 4697222	7.62	132.5	0.1	6.12	12.8

Based on the results obtained, we can conclude that the surrounding areas of the uncontrolled landfill sites in Western Georgia are less polluted than the similar locations in Eastern Georgia in terms of the components selected by us. However, some of the results of microbiological analysis as well as the amounts of heavy metal concentration, point out that special attention should be paid to the sample results in Adjara and Guria as these types of territories can create a hazard to human health.

THE OUTSKIRTS OF TBILISI

From the uncontrolled landfill sites in Tbilisi area, we have selected the following locations in order to collect the analysis samples: Little Gldani (Avchala), Janjgava Street; Tbilisi Sea (Cadet Corps); Digomi Area, Block 2 (the surrounding area of the Digmula River); and the surrounding area of the Vere River (behind the Zoo). On each of the locations, we have chosen one uncontrolled landfill site and one background area accordingly, from which we collected the analysis samples as well. The sampling locations are shown in Fig. 11–14 and featured on the interactive map (see Fig. 15).

Fig. 11. Tbilisi, Avchala, Janjgava Street

Fig. 12. Tbilisi Sea, Cadet Corps

Fig. 13. Tbilisi, Digomi Massive

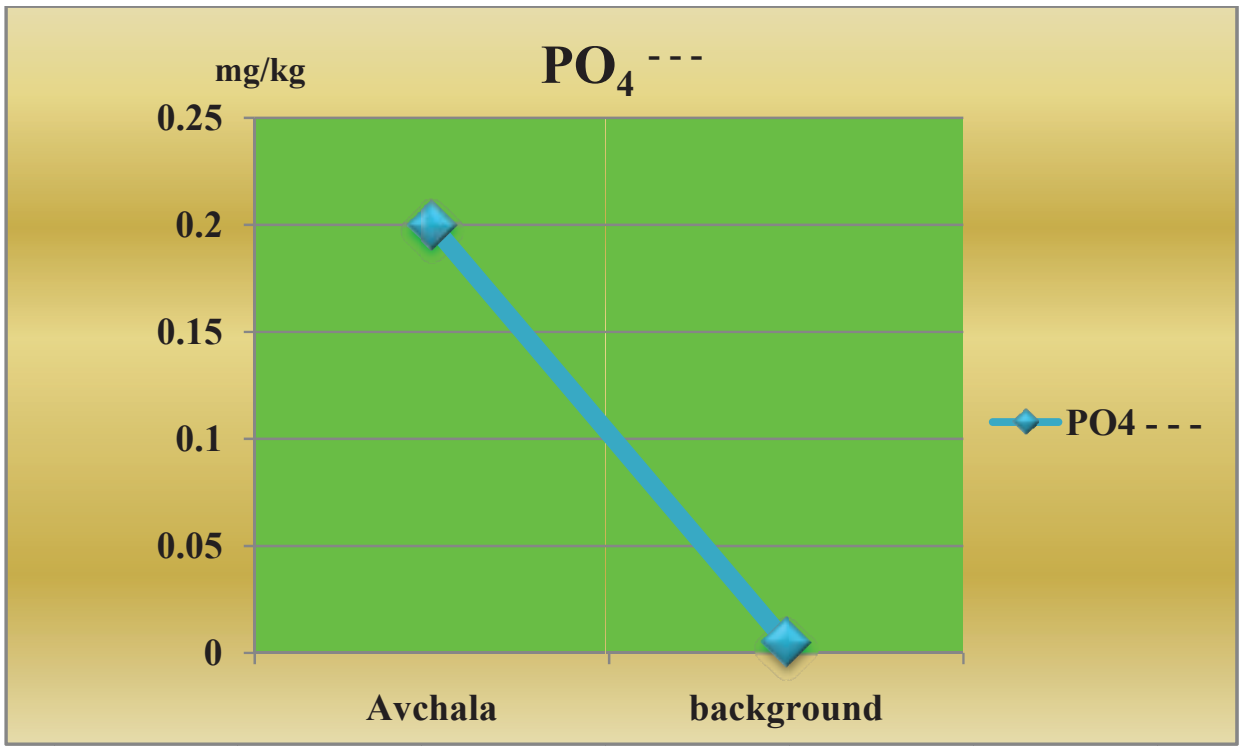
Figure 14. Tbilisi, the surrounding area of the Vere River

Fig. 15. Tbilisi interactive map and the sampling locations

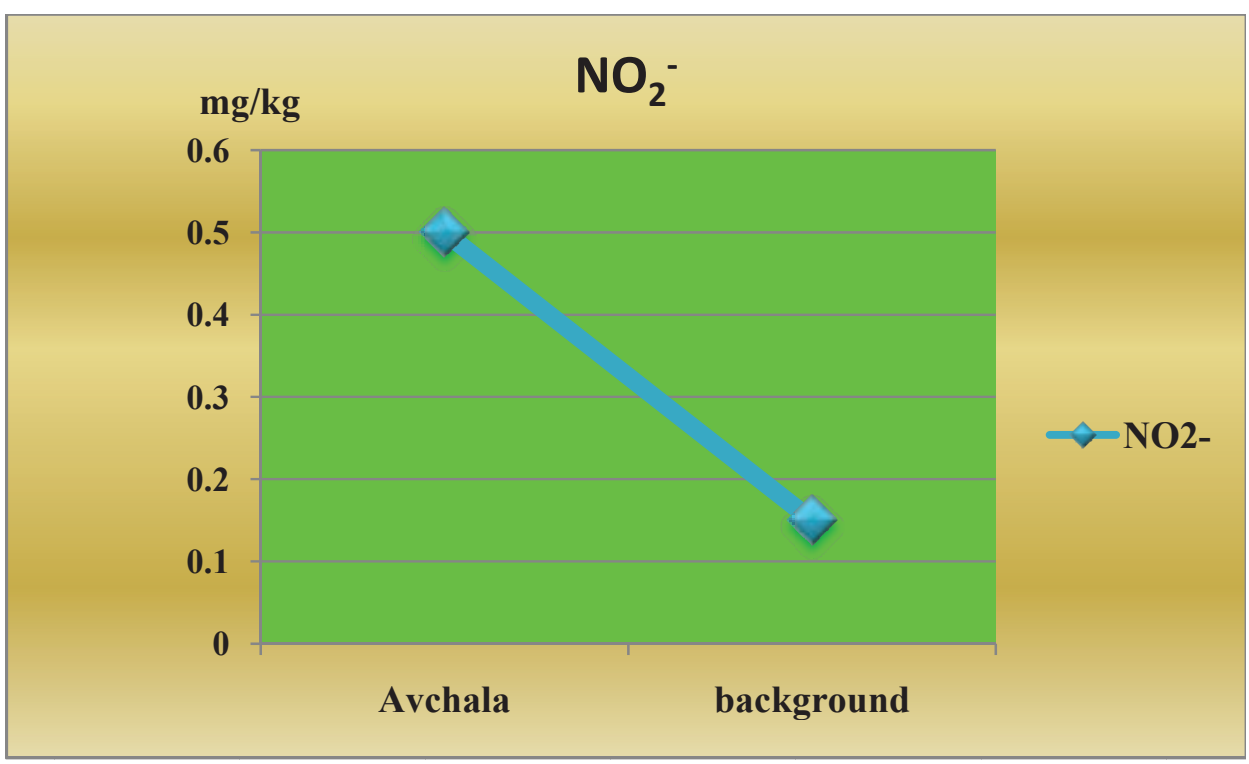
In the samples collected (soil, water), we assessed all those polluting ingredients that we had studied in Eastern and Western Georgia. Accordingly, we performed hydrochemical and microbiological analyses and using the portable device, we assessed physico-chemical properties of the river water samples in the field. The results are shown in Tables 57–59 and Graphs 47–58.

Table 57. The results of hydrochemical analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Tbilisi

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	pH	HCO_3^- mg/kg	NO_2^- mgN/kg	NO_3^- mgN/kg	PO_4^{3-} mg/kg	NH_4^+ mgN/kg	SO_4^{2-} mg/kg
Tbilisi Sea, the surrounding area of the Cadet Corps		484214 4624013	587	7.39	975	3.3	160	0.005	11.0	224.0
Tbilisi Sea (background)		484077 4624132	604	7.98	525.0	1.0	8.0	0.35	9.5	55.0
Tbilisi, Digomi Massive, Block 2		481057 4622578	418	7.18	1890	0.005	32.0	0.005	9.0	122.0
Tbilisi, Digomi Massive, Block 2 (background)		481021 4622558	429	8.04	378.0	0.005	2.0	0.1	9.0	4.0
Tbilisi, Little Gldani, Janjgava Street		483532 4628175	449	7.35	1330	0.5	12.5	0.2	7.0	4445
Tbilisi, Little Gldani, Janjgava Street (background)		483442 4628106	457	8.10	460	0.15	0.4	0.005	10.0	26.0
Tbilisi, the surrounding area of the Vere River (bridge)		480924 4618056	442	8.12	620.0	0.3	9.5	0.005	7.0	585.0
Tbilisi, "Mziuri" (background)		480935 4617970	426	8.21	255.0	0.02	0.11	0.005	8.0	2.3



Graph 47. The phosphate ion concentration in the soil samples collected in Avchala District, Tbilisi



Graph 48. The nitrite ion concentration in the soil samples collected in Avchala District, Tbilisi

Table 58. The results of microbiological analysis of the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Tbilisi

Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Total coliform titer	E. coli titer
Tbilisi Sea, the surrounding area of the Cadet Corps		484214 4624013	587	0.0001	**0.0001**
Tbilisi Sea (background)		84077 4624132	604	0.1	0.1
Tbilisi, Digomi Massive, Block 2		481057 4622578	418	0.001	0.001
Tbilisi, Digomi Massive, Block 2 (background)		481021 4622558	429	0.01	0.1
Tbilisi, Little Gldani, Janjgava Street		483532 4628175	449	0.0001	**0.0001**
Tbilisi, Little Gldani, Janjgava Street (background)		483442 4628106	457	0.01	0.1
Tbilisi, the surrounding area of the Vere River (bridge)		480924 4618056	442	0.001	0.001
Tbilisi, "Mziuri" (background)		480935 4617970	426	0.01	0.1

As we can see in the soil samples collected in Avchala District, the nitrite ion concentration is 3.5 higher than the background values, while the nitrate ion concentration is 31 times higher (Graphs 47–48). Based on microbiological analysis, the location can be categorized as heavily polluted (Table 57).

Some heavy metals (Cu, Zn, Pb, Cd) were also assessed in the abovementioned samples. The results are shown in Table 59 and Graphs 49–50.

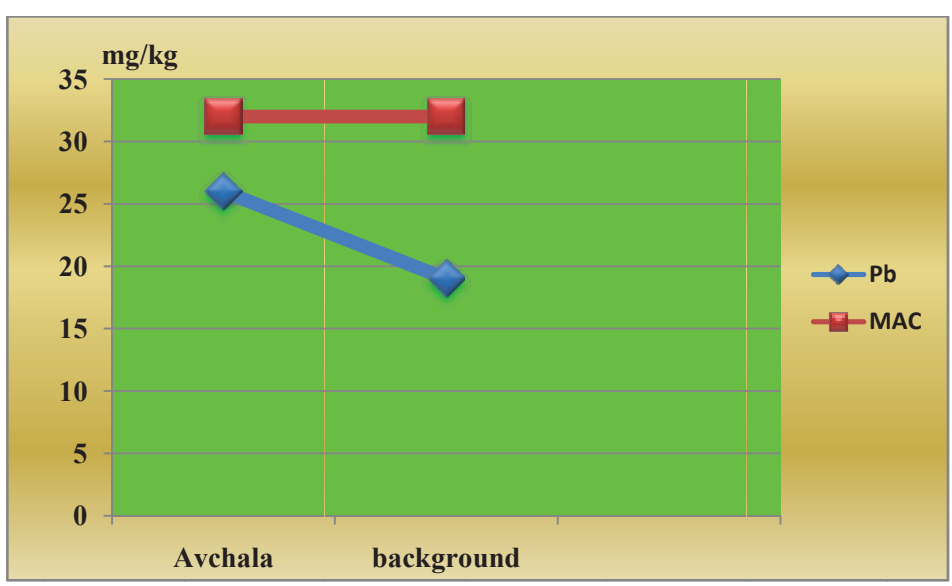
As we can see, the values of almost all heavy metals (except for cadmium) of the samples collected in Avchala District are insignificantly higher than the background values (Table 59, Graph 49–50).

The soil samples collected from the surrounding area of the Cadet Corps at Tbilisi Sea are characterized by the significantly increased nitrate ion concentration (the values are 20 times higher than the background data) and high concentration of total coliforms and E. coli. (Table 58, Graph 51).

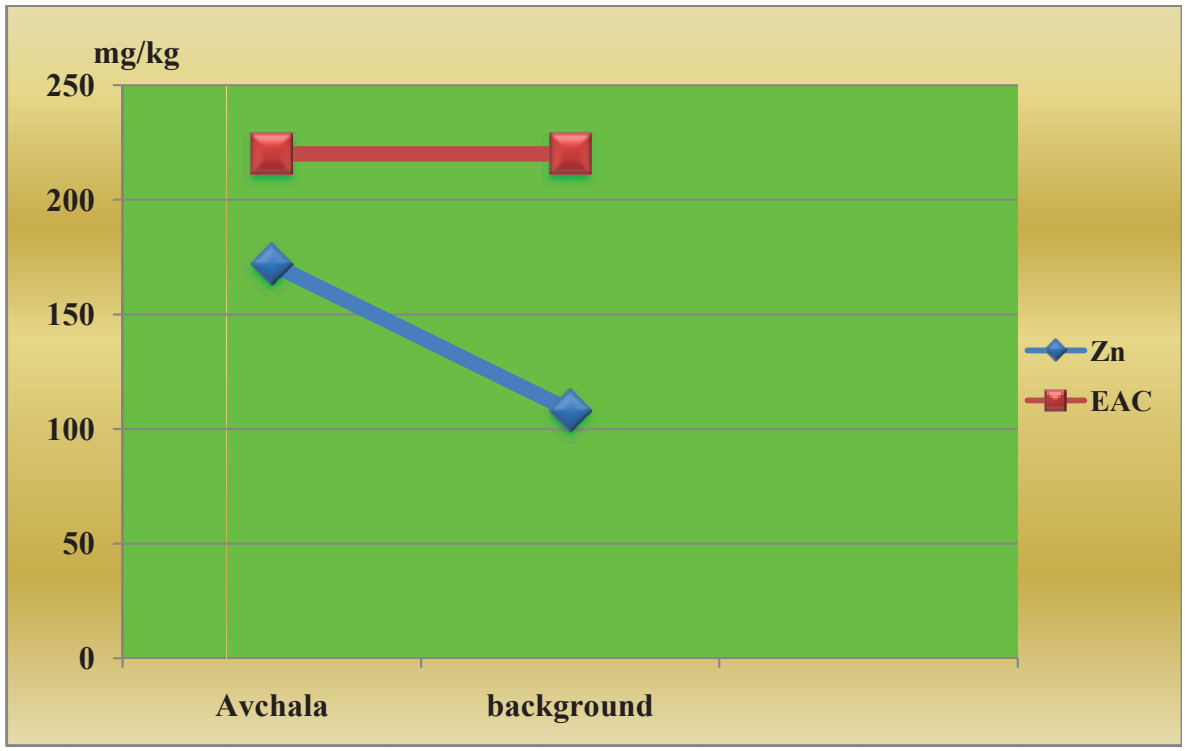
As for heavy metals, in the samples collected from Tbilisi Sea, only the concentrations of copper and zinc are increased (Table 59, Graphs 52–53).

Table 59. The heavy metal (Cu, Zn, Pb, Cd) concentration in the soil samples collected from the surrounding areas of the uncontrolled landfill sites in Tbilisi

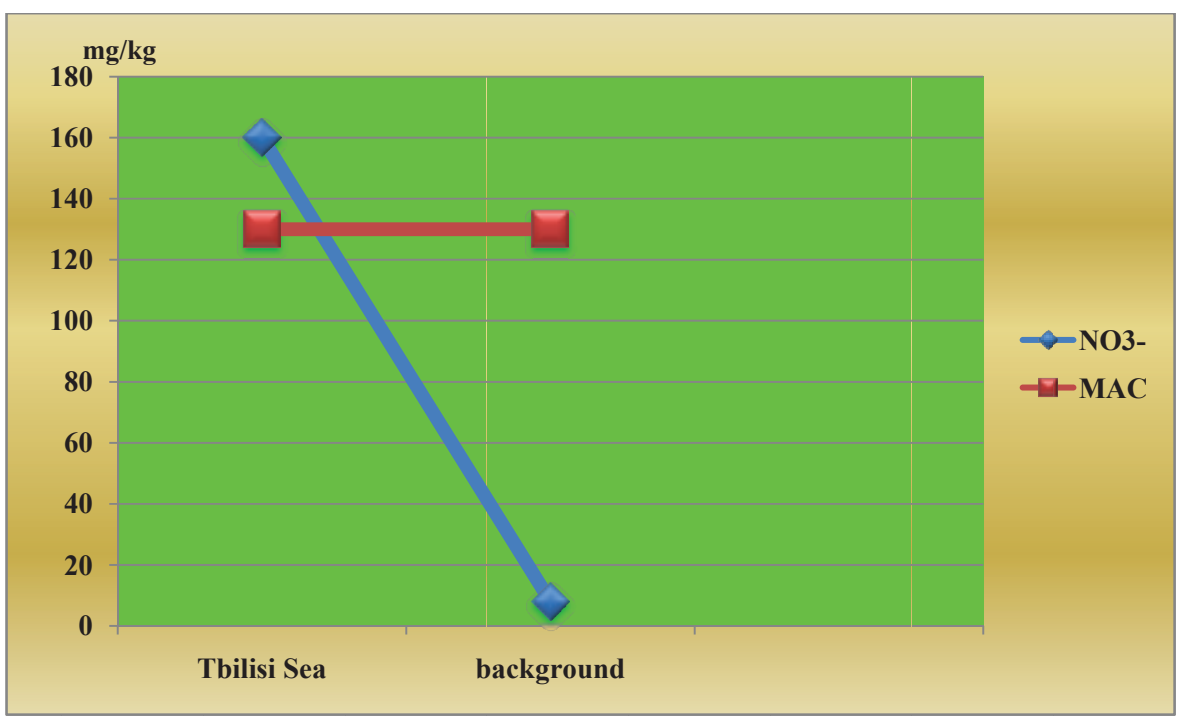
Sampling location	Sampling time	Coordinates	Altitude (m.a.s.l.)	Cu, ppm	Zn, ppm	Pb, ppm	Cd, ppm
Tbilisi Sea, the surrounding area of the Cadet Corps		484214 4624013	587	68	137	34	<2.5
Tbilisi Sea (background)		84077 4624132	604	43	98	32	<2.5
Tbilisi, Digomi Massive, Block 2		481057 4622578	418	54	115	36	<2.5
Tbilisi, Digomi Massive, Block 2 (background)		481021 4622558	429	50	101	30	<2.5
Tbilisi, Little Gldani, Janjgava Street		483532 4628175	449	52	172	26	<2.5
Tbilisi, Little Gldani, Janjgava Street (background)		483442 4628106	457	48	108	19	<2.5
Tbilisi, the surrounding area of the Vere River (bridge)		480924 4618056	442	115	77	14	<2.5
Tbilisi, "Mziuri" (background)		480935 4617970	426	38	76	25	<2.5
Maximum Allowable Concentration (MAC)						32	
Estimated Allowable Concentration (EAC)				132	220	130	2.0



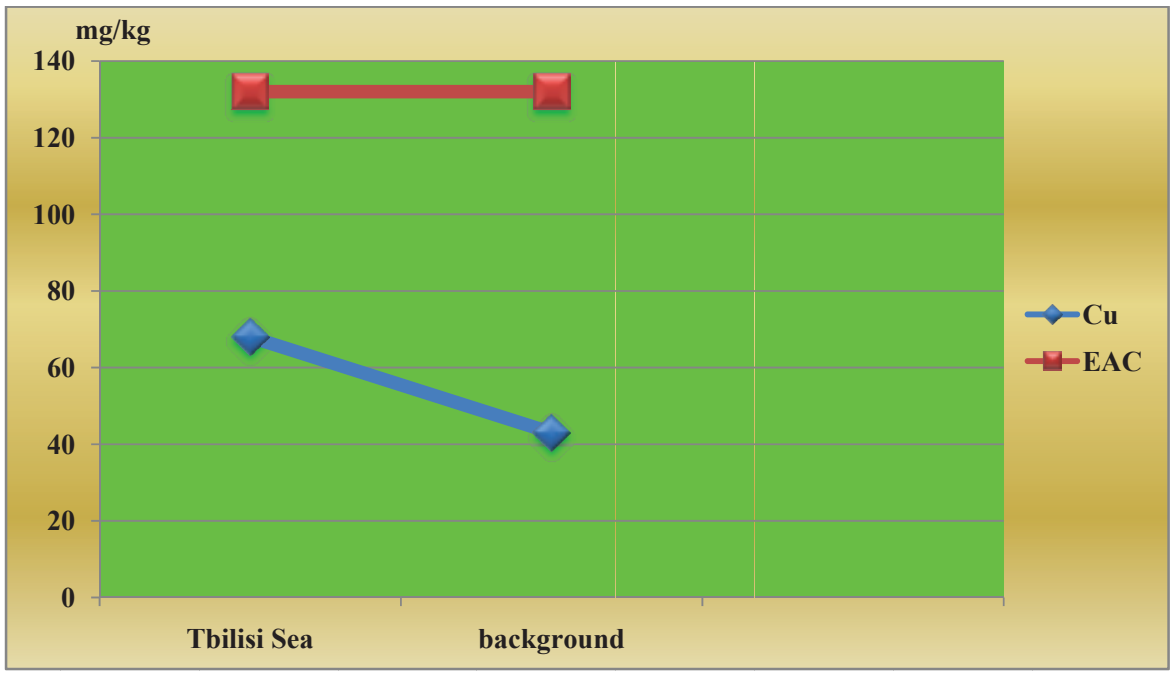
Graph 49. The lead concentration in the soil samples collected in Avchala District, Tbilisi



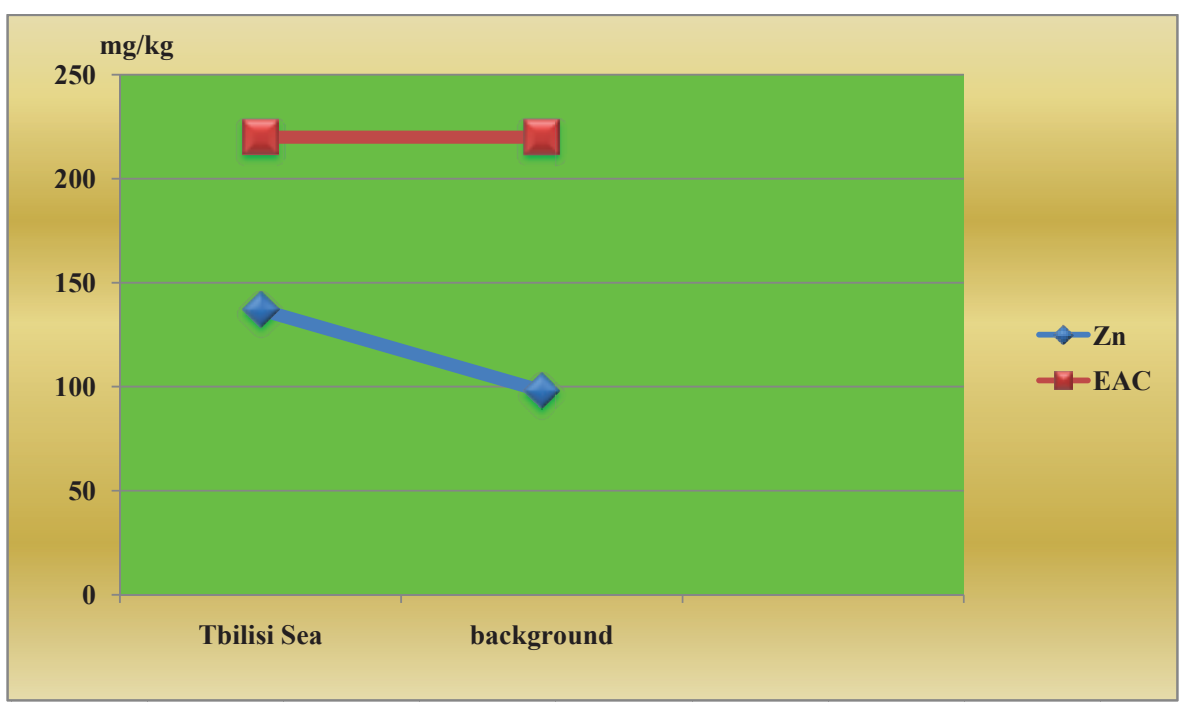
Graph 50. The zinc concentration in the soil samples collected in Avchala District, Tbilisi



51. The nitrate ion concentration in the soil samples collected in Tbilisi Sea area

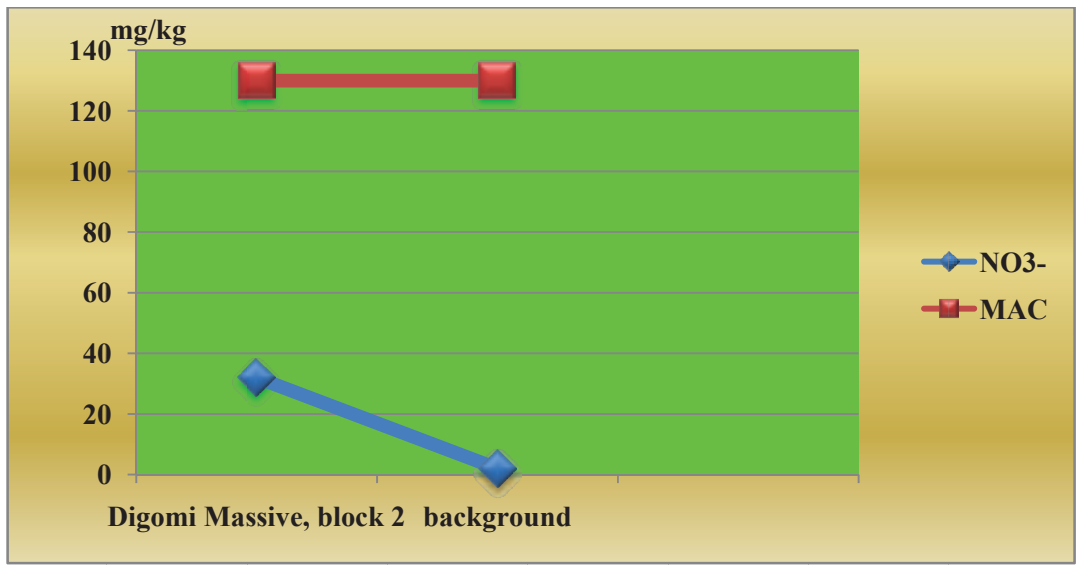


Graph 52. The copper concentration in the soil samples collected in Tbilisi Sea area

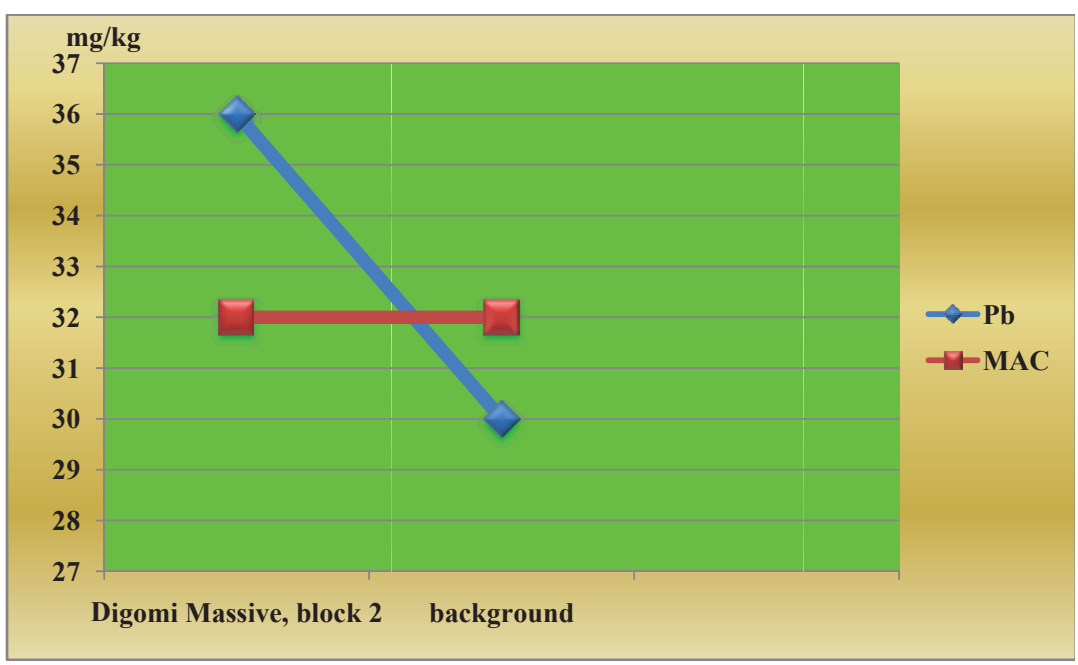


53. The zinc concentration in the soil samples collected in Tbilisi Sea area

The analysis samples collected in Digomi Massive, Block 2 (the surrounding area of the Digmula River), are notable for the high concentration of nitrate ions (16 times higher than the background level) and insignificant increase of the lead concentration (Tables 57–59; Graphs 54–55).

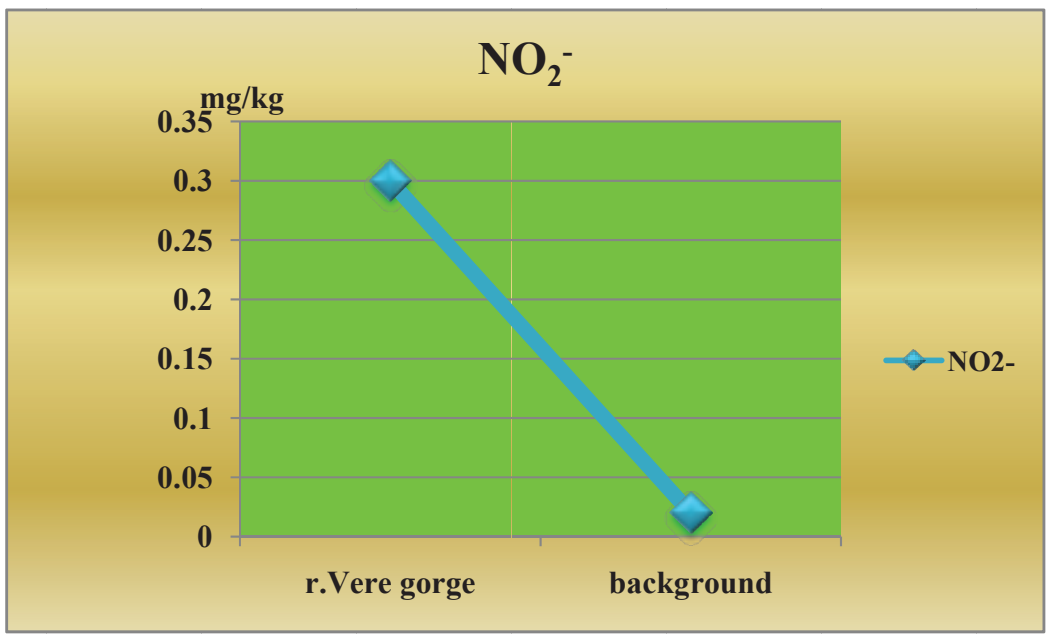


Graph 54. The nitrate ion concentration in the soil samples collected in Digomi Massive of Tbilisi

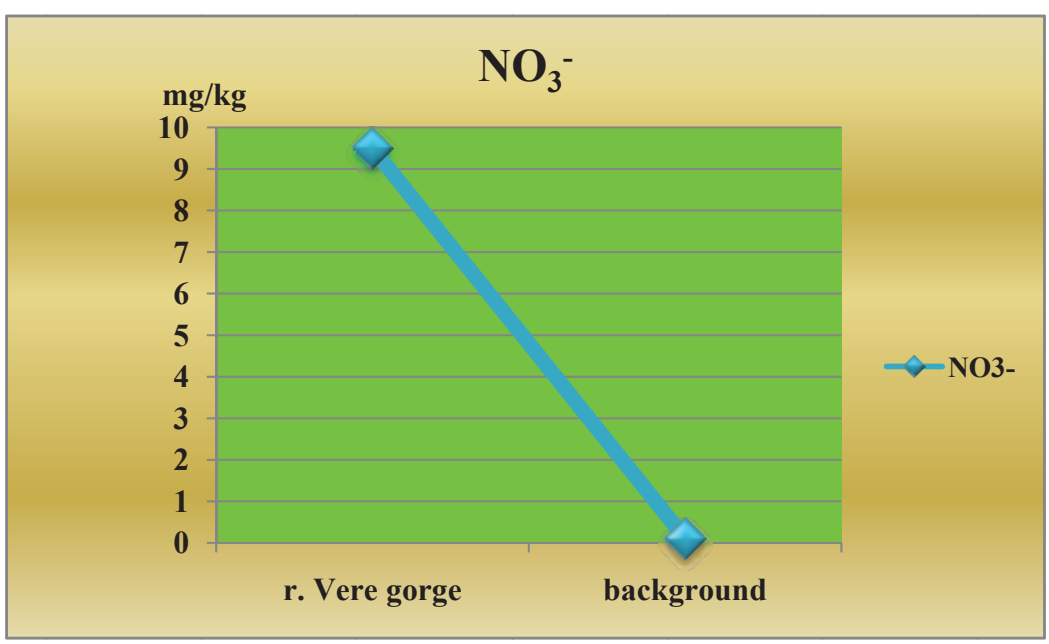


Graph 55. The lead concentration in the soil samples collected in Digomi Massive of Tbilisi

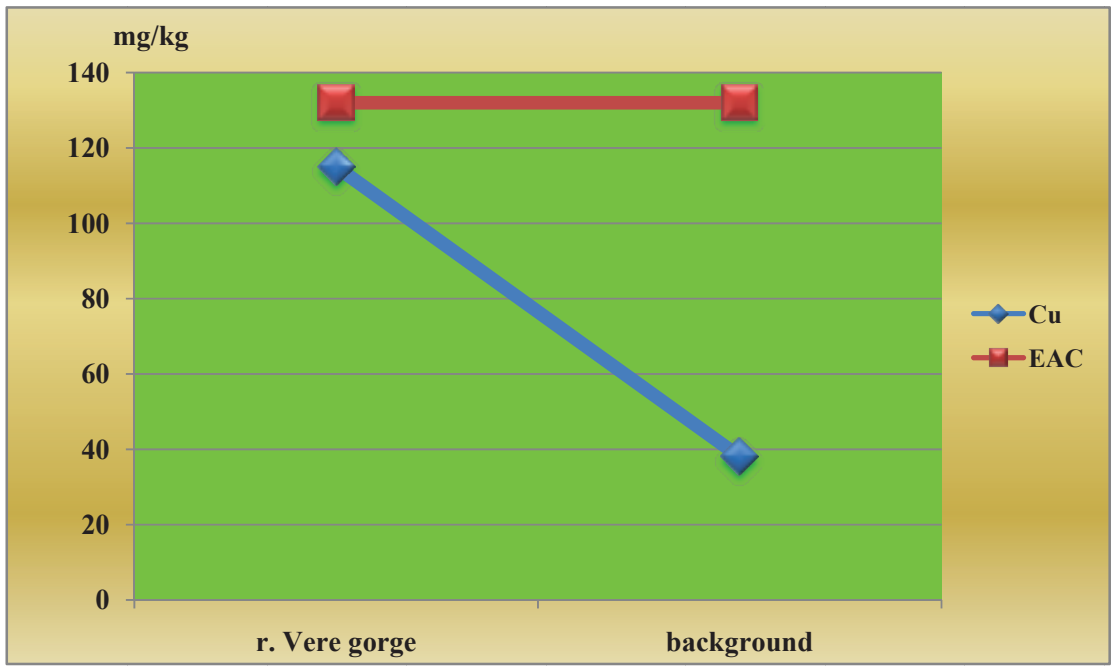
In the soil samples collected from the surrounding area of the Vere River, the nitrite and nitrate ion concentrations were significantly higher than background values (Graph 56–57). As for heavy metals, particularly high concentration of copper was assessed (Graph 58).



Graph 56. The nitrite ion concentration in the soil samples collected from the surrounding areas of the Vere River gorge (Tbilisi)



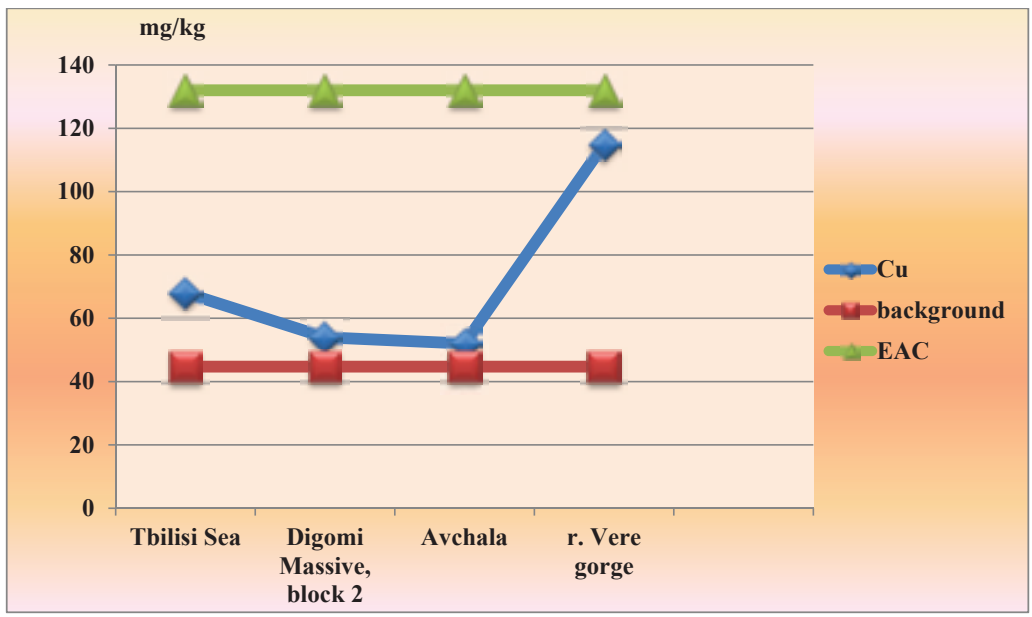
Graph 57. The nitrate ion concentration in the soil samples collected from the surrounding areas of the Vere River gorge (Tbilisi)



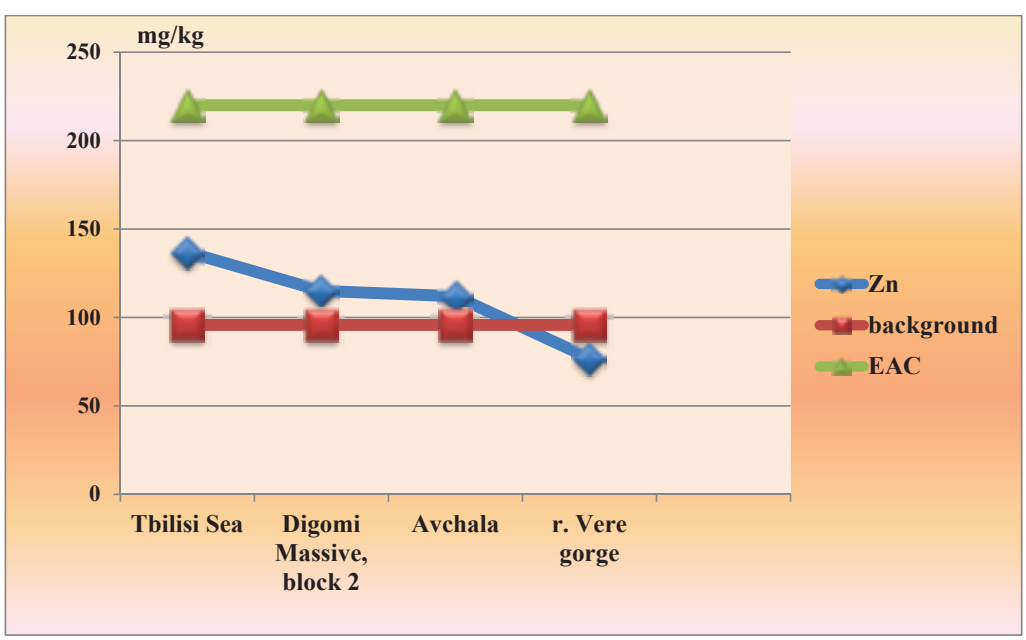
Graph 58. The copper concentration in the soil samples collected from the surrounding areas of the Vere River gorge (Tbilisi)

COMPARATIVE ANALYSIS

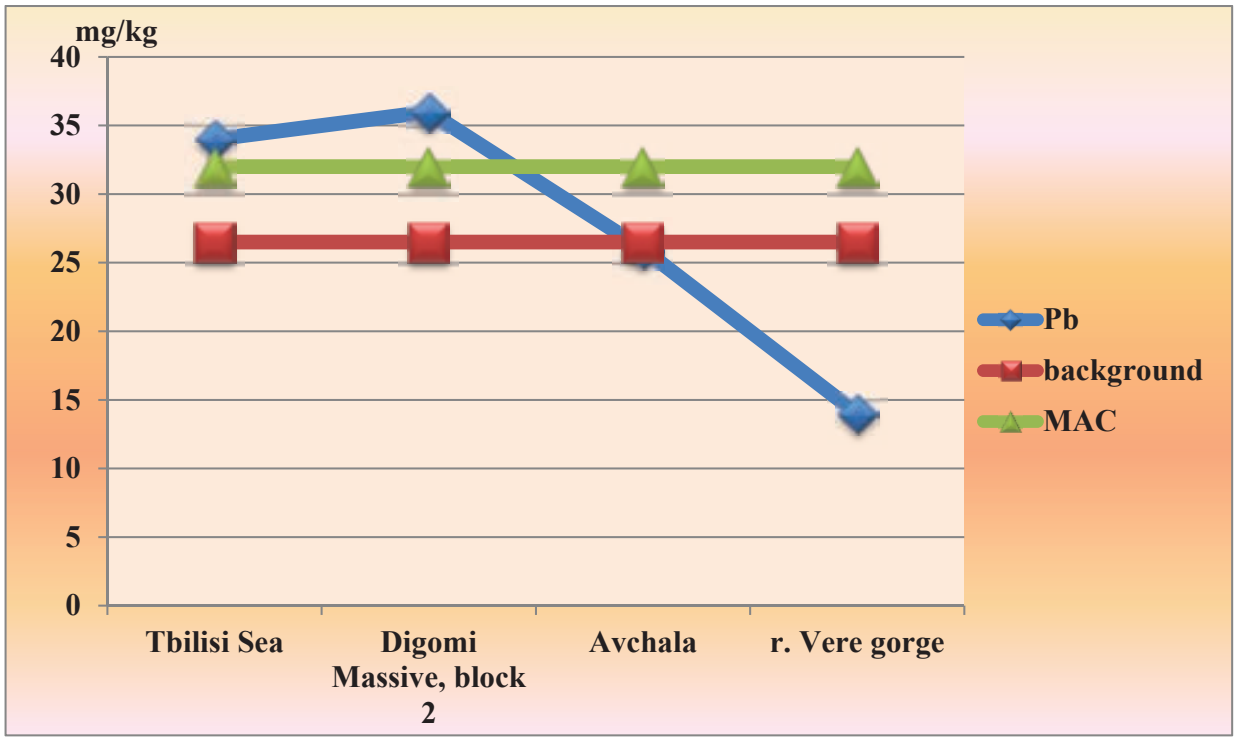
In order to observe the dynamics of changes in the concentration of heavy metals in the soil samples collected, for each heavy metal we have calculated average background concentrations and then compared them to the actual concentrations of different heavy metals in the same location (See Graphs 59–61).



Graph 59. Dynamics of changes in the concentration of copper in the soil samsples collected in Tbilisi areas



Graph 60. Dynamics of changes in the concentration of zinc in the soil samples collected in Tbilisi areas

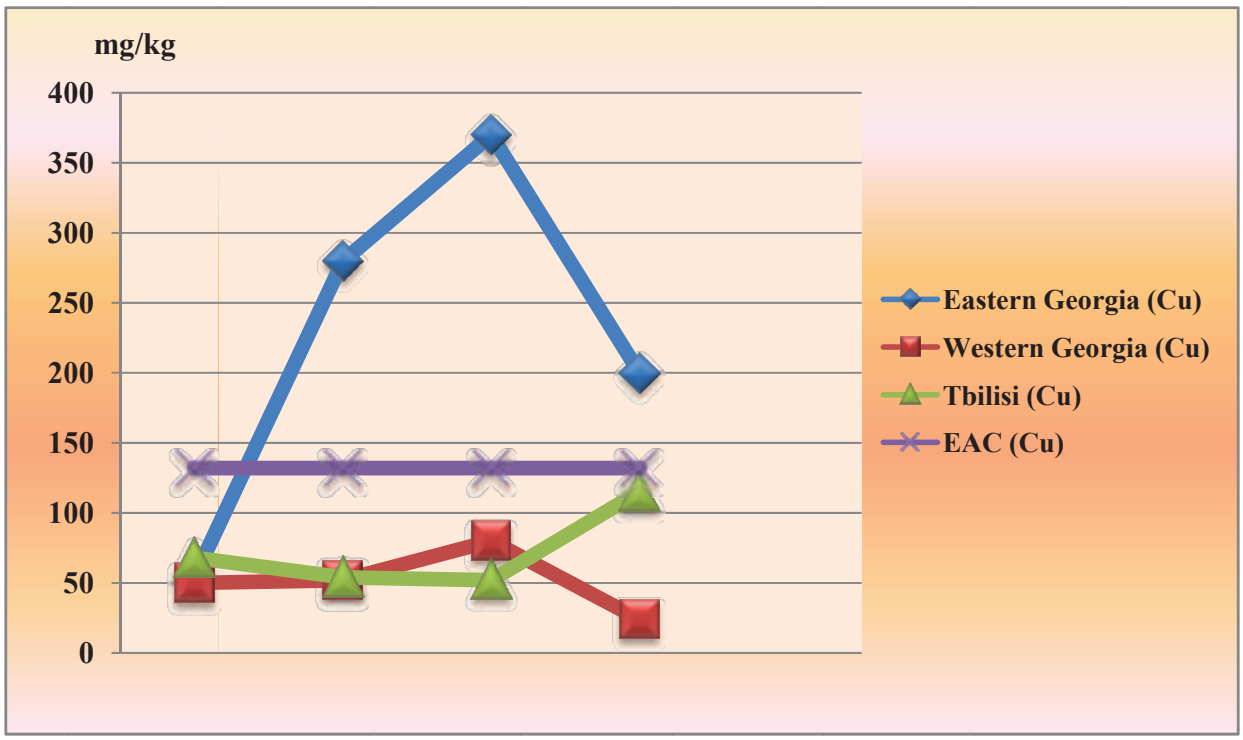


Graph 61. Dynamics of changes in the concentration of lead in the soil samples collected in Tbilisi areas

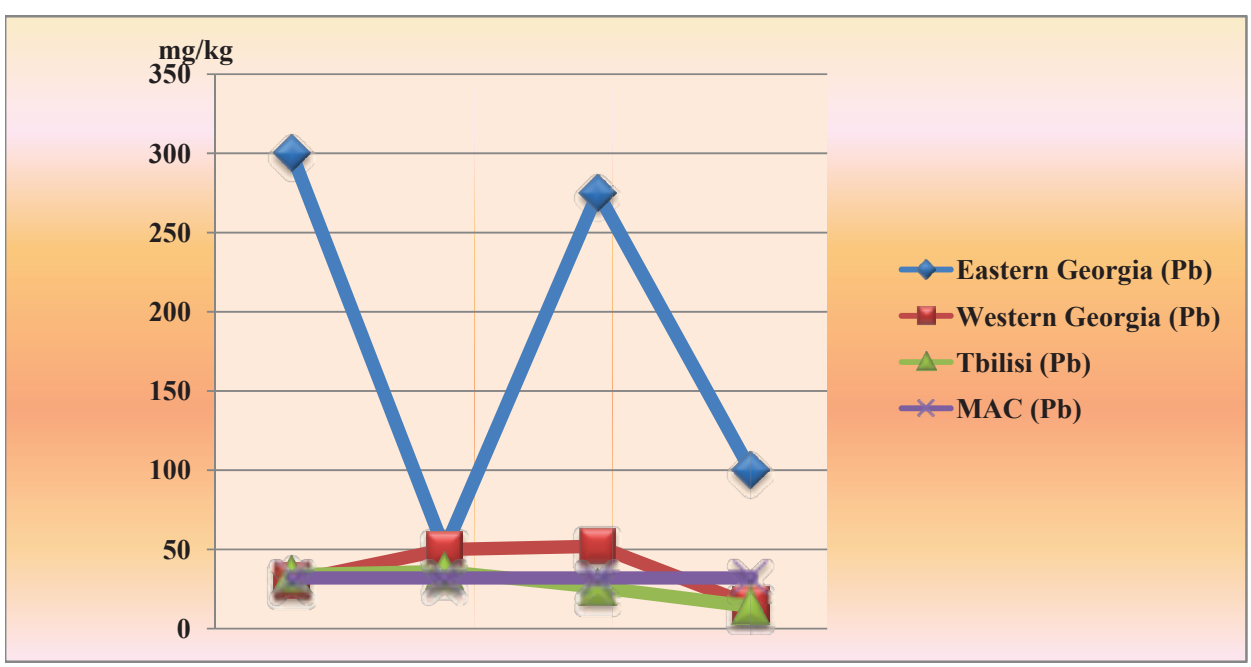
It was obvious that the highest concentration of copper was in the surrounding area of the Vere River gorge, the highest concentration of zinc was determined in Avchala District, while the highest concentration of lead is found in Digomi Massive (Graphs 57–59). It can be said that the uncontrolled landfill sites located on the outskirts of Tbilisi have an impact on the ecosystems of the surrounding areas to some extent and accordingly, play a significant role in the pollution process.

It is also interesting to compare the results obtained from Eastern Georgia, Western Georgia, and the outskirts of Tbilisi in order to observe the dynamics of changes in the concentration of a particular contaminant (for example, the highest concentration of heavy metals). Graphs 62–64 show the results of this type of comparative analysis.

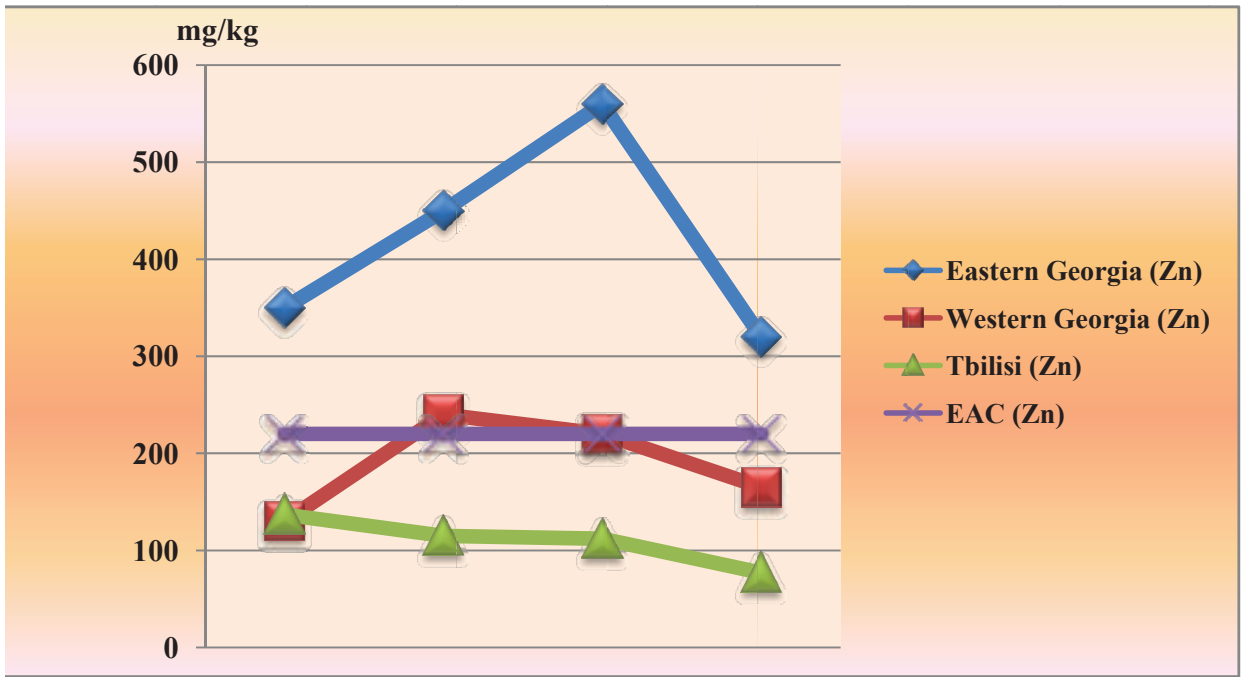
As we can see, the most intensive anthropogenic impact on the surrounding areas of the uncontrolled landfill sites was assessed in Eastern Georgia. The high level of pollution of the research samples collected in Eastern Georgia is obvious for any heavy metal concentration.



Graph 62. The copper concentration in the soil samples collected in Eastern Georgia, Western Georgia and the outskirts of Tbilisi



Graph 63. The lead concentration in the soil samples collected in Eastern Georgia, Western Georgia and the outskirts of Tbilisi



Graph 64. The zinc concentration in the soil samples collected in Eastern Georgia, Western Georgia and the outskirts of Tbilisi

POLLUTING INGREDIENTS AND THEIR IMPACT ON HUMAN HEALTH

This work represents the list of the polluting components defined within the framework of the project as well as the diseases they may cause in humans in case of contact with them (Tables 60–62). It should also be noted that the pollutants appear on landfill sites from different sources and pollute both the surrounding areas and the environment in general. Having analyzed the data obtained from this research, we have a reasonable belief that such a threat exists.

Table 60. The list of diseases caused the entrance of some heavy metals (Cu, Zn, Pb, Cd) into the human body

N	Name of Element	Concentration in the human body	Changes in human body
1.	**Zn**	>150 mg/day	• Weakened immune system • Erosion of the stomach wall • Hemogram (blood count) changes (decreased iron levels) • Deterioration of liver function • Deterioration of prostate function
2.	**Cu**	>1, 01 mg/l of blood	• Gastrointestinal perforation • Decreased kidney function (zinc is mainly concentrated in kidney tissue)
3.	**Pb**	1000–1200 mkg/l of blood 800“ ----“ 500“ ----“ 400“ ----“ 300“ ----“ 200–300“ ----“ 150–200“ ---“	• Signs of encephalopathy • Anemia • Decreased production of hemoglobin, mental stress • Dramatically increased amounts of alanine in the urine • Dysfunction of peripheral nervous system • Dramatically increased amounts of protoporphyrin in men’s red blood cells • Dramatically increased amounts of protoporphyrin in women’s red blood cells
4.	**Cd**	1–5 mkg	Decreased kidney function (stimulates kidney stone accumulation, decreased lung function, tumoral diseases)

Table 61. The list of diseases caused the entrance of some nitrogen containing compounds into the human body

N	Name of element	Concentration in the human body	Changes taking place in the human body
1.	NO_2^-	>0, 23 mg/m^3	• Deterioration of olfaction • Irritation of respiratory tract tissues • Deterioration of eyesight • Causes lack of oxygen (hypoxia) in the body
2.	NO_3^-	>312 mg/per day	• Deterioration of gastrointestinal function • Hypoxemia • Weakening of cardiovascular system (dramatic fall in blood pressure)
3.	$NH_4^+(NH_3)$	>0, 4–0, 7 mg/l (in blood)	• Nausea, coma • Common tissue hypoxia

Table 62. The list of diseases caused the entrance of some bacteria into the human body

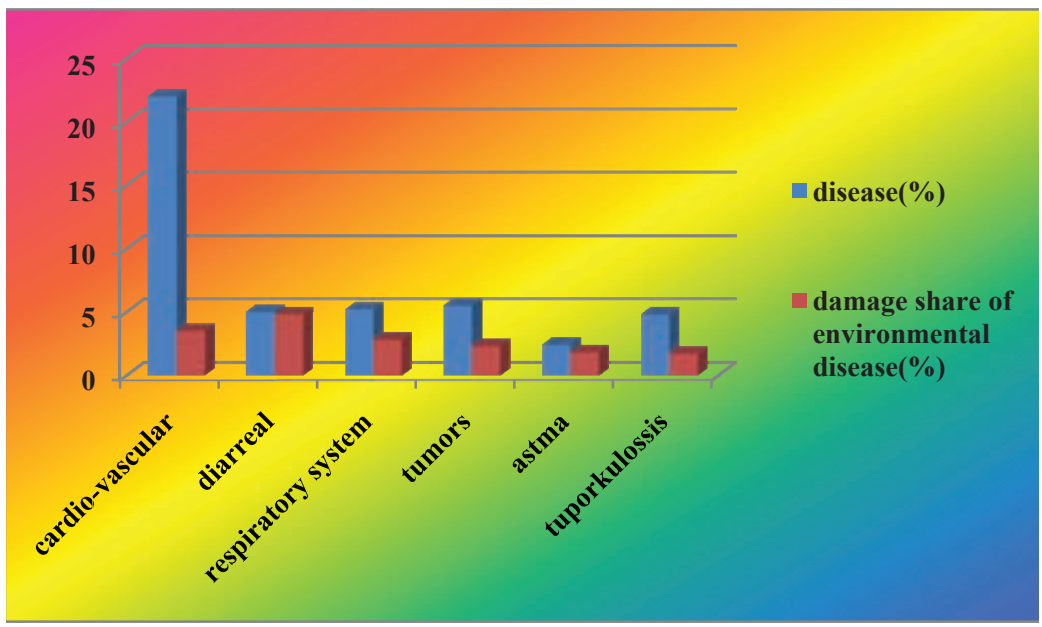
N	Name of bacteria in the human body	Type of disease
1.	E. coli	Diarrhea, colitis, peritonitis, prostate, sepsis, meningitis, Disorder of gut function, inflammation of urinary system
2.	Faecal streptococci	Disorganization of respiratory system function, scarlet fever, dramatic worsening in rheumatic diseases, bronchitis, pneumonia, lymphadenitis, meningitis, periodontitis, pharyngitis, endocarditis

The pollutants reviewed by us are not found at the landfill sites by chance. They are contained in different products or items and accordingly, appear on these sites (see Table 63).

Table 63. Possible ways of occurring polluting components on the landfill sites

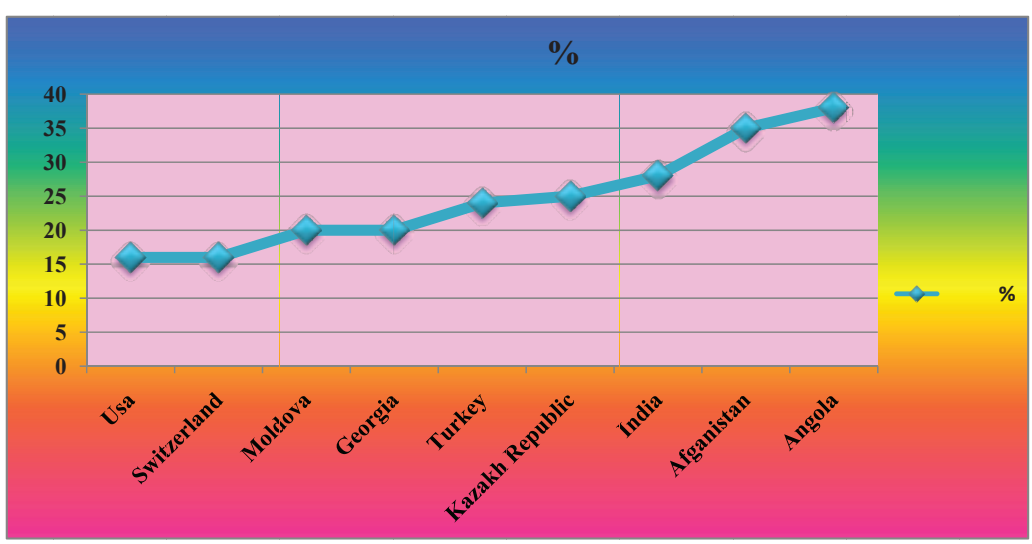
N	Component	Type of product	Others
1.	**Cu**	Spinach, buckwheat, potatoes, cereals, onions, carrots, tomatoes, cabbage, beans, garlic, nuts	Condensers, batteries, various home appliances, electronics
2.	**Zn**	Nuts, Greek nuts, canned beef, sunflower seeds, maize, cauliflower, cicer	Cosmetic products, different types of ointment, health products (medications)
3.	**Pb**	Rice, beans, cicer, oats	Batteries, paints, accumulators, ceramic works, cosmetic products
4.	**Cd**	Vegetables, cereals, potatoes	Tires, paints, tobacco, cigarette smoke

The polluted environment may become the source of various diseases in any country. Sometimes it is the force that provokes this process. Graph 65 shows the correlation between the environmental pollution levels and the disease spread dynamics.



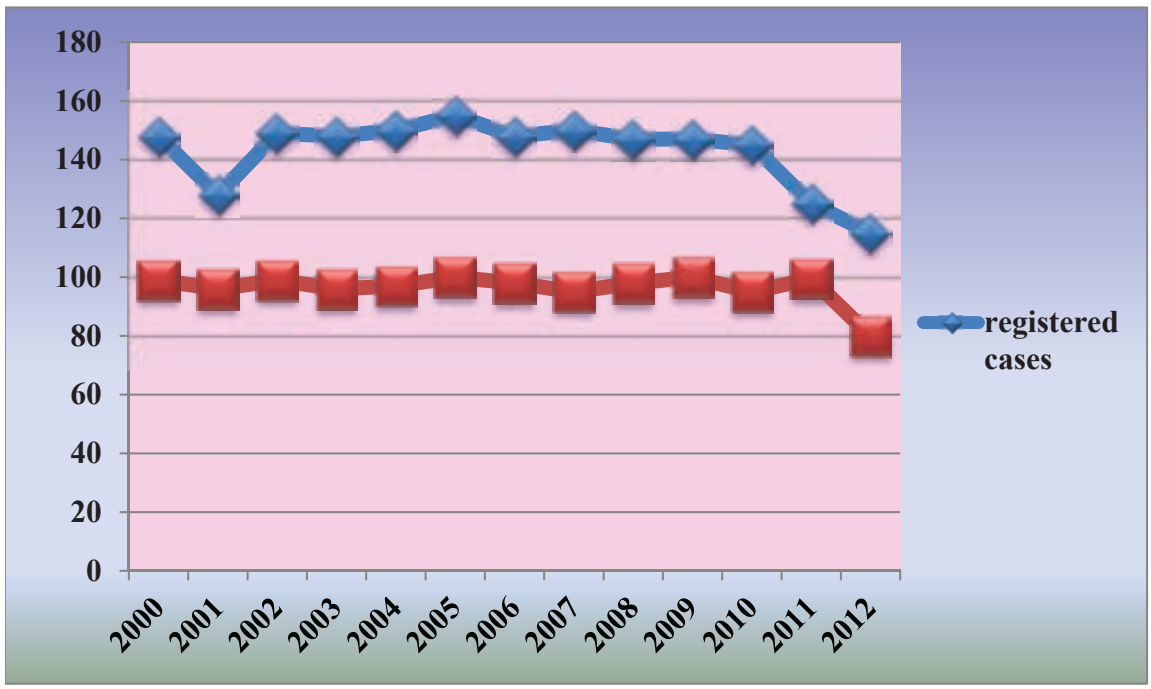
Graph 65. Share of environmental pollution in the spread of some existing diseases

The polluted environment may also contribute to the mortality rate. In different countries, this is represented in different ways (see Graph 66).

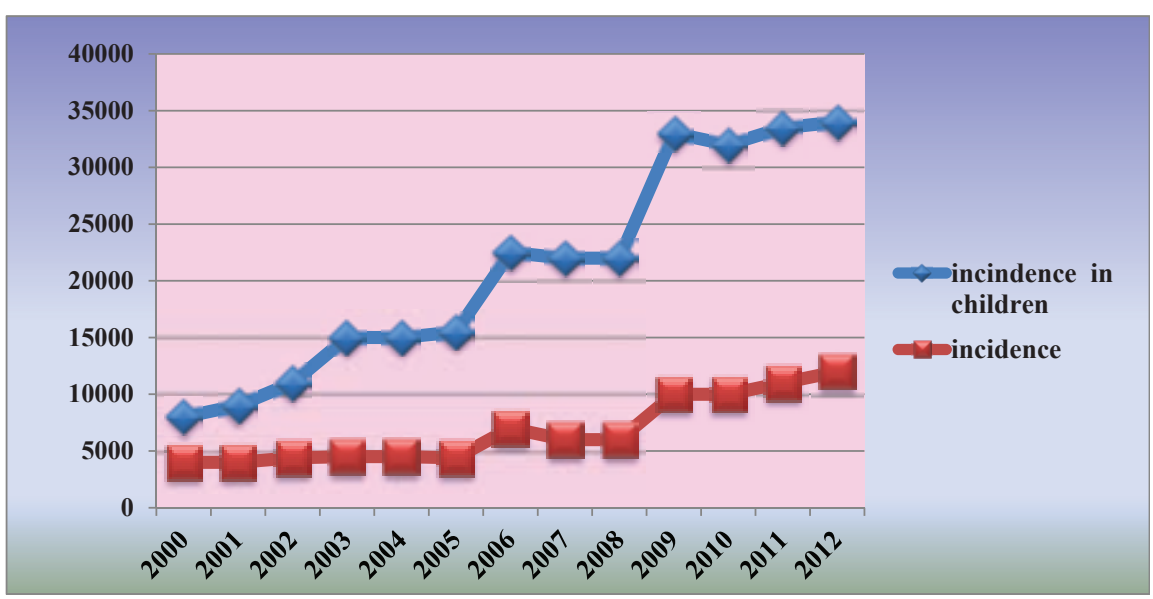


Graph 66. Share of negative environmental impact on the mortality rate according to the countries

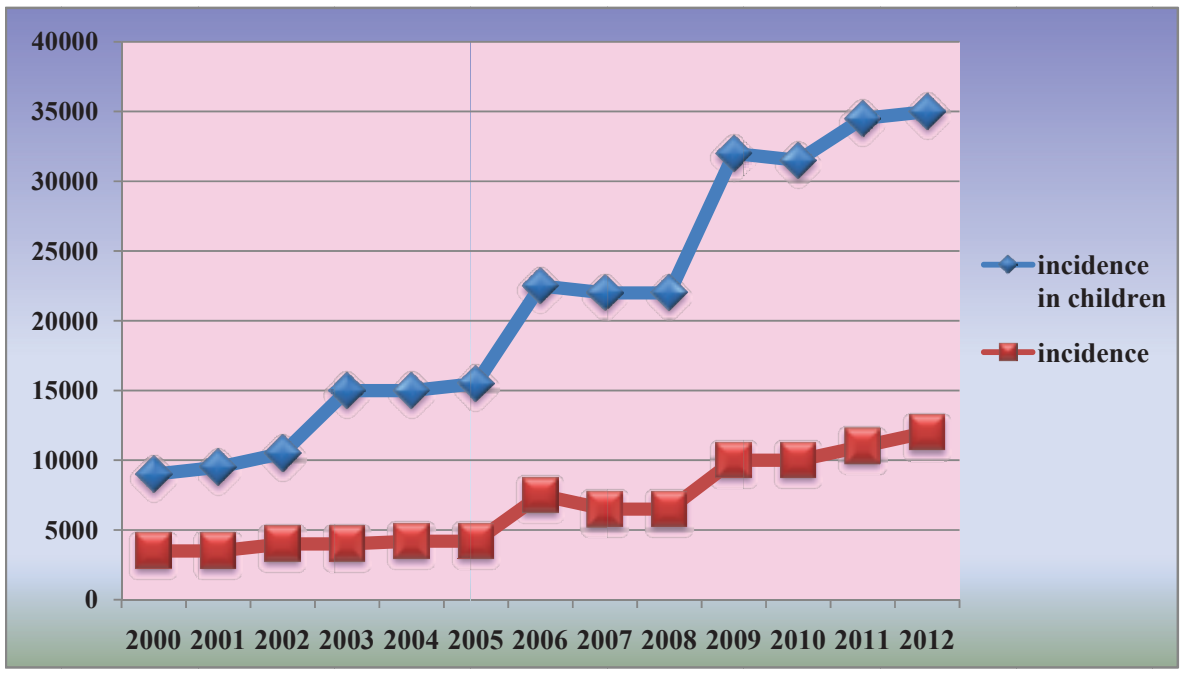
DYNAMICS OF THE MOST COMMON DISEASES IN GEORGIA IN RECENT YEARS



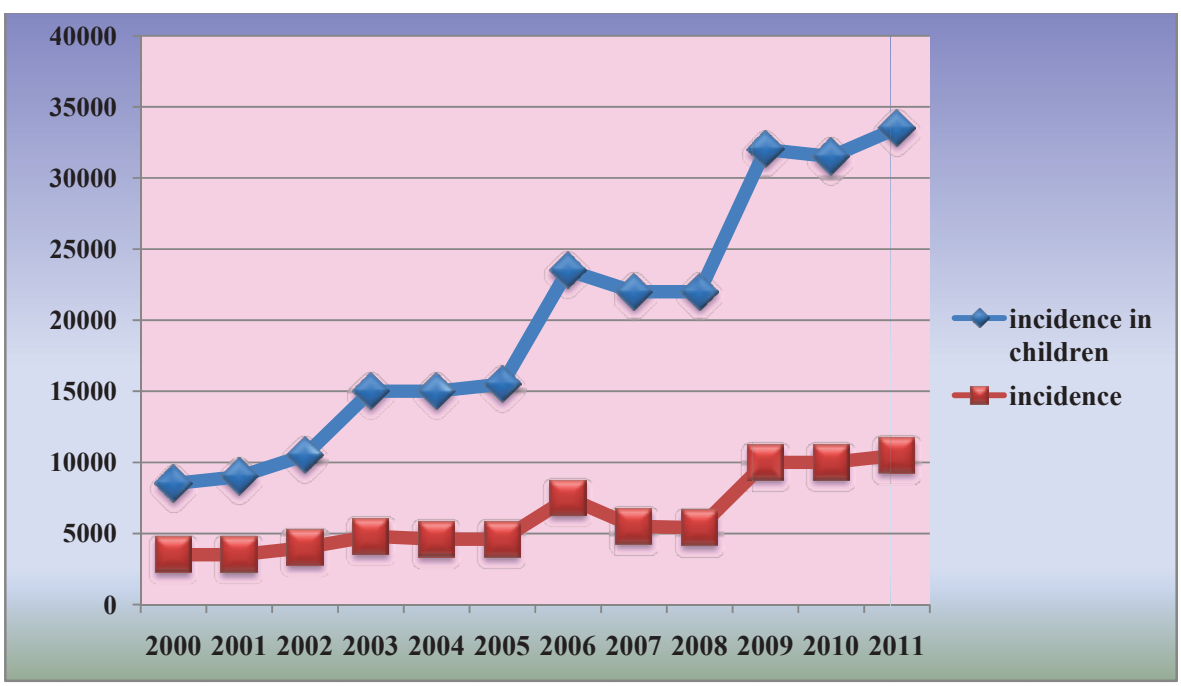
Graph 67. Registered and new cases of tuberculosis (rate - per 100,000 inhabitants), Georgia



Graph 68. Infectious and parasitic diseases, incidence rates and hospitalization, rate – per 100,000 inhabitants, Georgia

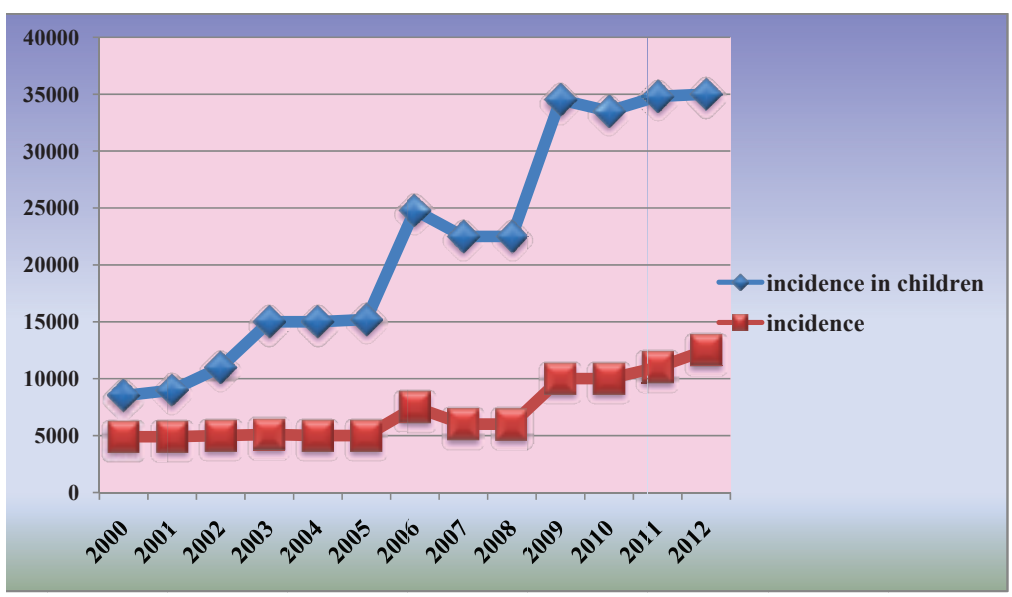


Graph 69. Hepatitis B and hepatitis C incidence rates per 100,000 inhabitants, Georgia



Graph 70. Acute myocardial infarction, incidence rates and hospitalization per 100,000 inhabitants, Georgia

Graph 71. Incidence rates of malignant tumor, Georgia



Graph 72. Incidence rates of respiratory system diseases, Georgia

Based on the performed research and analysis of the results obtained, it can be said that uncontrolled landfill sites play a significant role in the pollution process of the ecosystems (water, soil, air). From the polluting components, we have assessed carcinogenic elements such as copper and cadmium as well as E. coli and Faecal streptococci the concentration of which—in our case—very often exceeds the Maximum Allowable Concentrations. All this suggests that the uncontrolled landfill sites not only pollute the surrounding areas and the environment, in general, but they represent rather create a significant hazard to human health. Accordingly, the surrounding areas with high levels of pollution should be immediately freed from such landfill sites.