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Compilation of groundwater monitoring maps for the Mitrovica region in Kosova

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Abstract: Groundwater is the most important natural resource required for drinking to many people. The study presents a case study of heavy metal pollution in groundwater at the Mitrovica region, Kosovo. A numerous heavy metals and their parameters were considered in the analysis. The aim of the study is monitoring the presence of heavy metals in groundwater by developing of spatial database and compilation of thematic maps through GIS technology. GIS is used to represent the spatial distribution of the heavy metals. In order to represent the spatial distribution are used two interpolation techniques such as IDW and Spline. As well as the study involves the comparison analysis between IDW and Spline interpolation techniques. The populated data in GIS such as spatial and non-spatial data are based in the field investigations and field surveying as well as in the office data processing and calculating. In order to monitor groundwater pollution are used two known indices in worldwide, known as Heavy Metal Pollution Index (HPI) and Metal Index (MI). The final datasets of the study will include a numerous raster maps of groundwater monitoring in Mitrovica. The groundwater monitoring maps produced, represent the situation of 2018 and will be used to support environmental management. The GIS based on monitoring of heavy metal in groundwater derived from this study, is an attempt for the first time in Kosovo to determine groundwater pollution and to identify places with high pollution within the study area.

1. Introduction

Groundwater resources are dynamic in nature and are affected by such factors as the expansion of irrigation activities, industrialization and urbanization, hence monitoring and conserving the important is essential (Rokbani et al., 2011). The quality of groundwater is defined in terms of it chemical parameters. Ascertaining the quality is crucial before its use for various purposes such as drinking, agricultural, recreational and industrial uses (Sargaonkar and Deshpande, 2003; Khan et al., 2003).

Heavy metals are among the most common environmental pollutants, and their occurrence in water and biota indicate the presence of natural or anthropogenic sources (Akoto et al., 2008; Adaikpoh et al. 2005). Heavy metal contamination in water is recognized as a severe environmental problem and therefore the study related to water contamination has become important. The pollution parameters are generally monitored for the assessment of quality of any system which gives an idea about the pollution with reference to particular parameters (Balakrishnan and Ramu, 2016). Heavy metal pollution index (HPI) is defined as a rating reflecting the composite influence of different dissolved heavy metals (Sirajudeen et al., 2014). HPI is a powerful tool for ranking amalgamated influence of individual heavy metal on the overall water quality and a view of the suitability of ground water for human consumption (Reza and Singh, 2010; Rizwan et al., 2011). The critical pollution index value for drinking water should be less than 100. Another index is the general metal index (MI) for drinking water, which takes into account possible additive effect of heavy metals on human health that help to quickly evaluate the overall quality of drinking water (Abdullah, 2013). In this study, 10 groundwater samples have been collected in Mitrovica region and have been analyzed various heavy metals like As, Cr, Cu, Ni, Pb, Zn and Cd. The performed results will be compared with drinking water standards prescribed by World Health Organization (WHO). Then, the analyzed results were taken into GIS environment.

Groundwater monitoring has been based on laboratory investigation and applying of Geographic Information System (GIS) has made it very easy to integrate various databases. One of the most promising systems used by earth scientists is the Geographic Information System (GIS) (Maliqi et al., 2015). GIS can be a powerful tool for developing solutions for water resources problems, assessing water quality, determining water availability, preventing flooding, understanding the natural environment and for managing water resources on a local or regional scale (Ferry et al., 2003).

From GIS, spatial distribution mapping for various pollutants can be done (Raikar and Sneha, 2012). The aim of this study is to evaluate the spatial distribution of heavy metal presence in groundwater by interpolation techniques. In order to determine the spatial distribution of groundwater pollution are used to known spatial interpolation techniques such as IDW and Spline interpolation**.** They produced pollution maps of groundwater contaminants using IDW and Spline indicators. Based on interpolation indicators the study area can be classified into different classes (class I to class VI).

In the present study, a groundwater pollution maps are important for drinking purposes and as indication of potential environmental health problems. The author’s goal is to monitor the groundwater heavy metal pollution index and metal index by an integrated the Geographic Information System (GIS) and to generate groundwater Heavy Metal Pollution Index (HPI) map as well as Metal Index (MI) map based on traditional water quality analysis.

2. Research objectives

The main goal of the study is demonstrating the use of GIS technology in groundwater monitoring and assessment within Mitrovica region. Developing of spatial database and compilation of groundwater monitoring maps will be developed and demonstrated in the present study.

The study objectives were addressed as follow:

- Developing data structure and thematic layers for groundwater monitoring and assessment within study area.
- Developing the spatial database and populating with attribute data its thematic layers, with focus for Heavy Metal Pollution Index (HPI) and Metal Index (MI) data.

- Compilation of serial thematic maps for monitoring of groundwater quality.
- Compilation of time series map as the base for further groundwater monitoring and assessment in this region.
- Identifying the places with high level of heavy metal pollution in groundwater in this region.
- Implementation of spatial interpolation techniques into GIS environment in order to perform results.
- Finally, the demonstration the use of GIS technology for environmental assessment and monitoring.

3. Study area

The Mitrovica is bounded in the north part of Republic of Kosova, only 25 km from the capital Pristina (Maliqi and Penev, 2018). The stuy area extends along to shores of the Iber and Sitnica rivers. It is located between the Latitude 42°57’02’’ & Longitude 20°54’36’’ in the North and Latitude 42°52’13’’ & Longitude 20°54’19’’ in the South (Figure 1). Total area covered 41 km^2, the minimum elevation is 502m and the maximum elevation is 991m whereas the most of the area is covered by highlands. According to the meteorological data for the Republic of Kosovo, the weather in subject region is continental with warm summers and cold snowy winters. According to WorldClim – Global Climate Data geoportal (www.worldclim.org), the annual average precipitation is 720 mm and moderate winds blowing predominantly from the northeast, average speed ranges 20 m/sec to 4.4 m/sec. In this part of the country, the winters are colder with medium temperatures above –10 °C, but sometimes down to –26 °C. The summers are very hot with average temperatures of 20 °C, sometimes up to 37 °C. The landscape consists of a system of hills and plateaus of flattened surfaces. The study area record two main seasons (wet and dry season). The wet season begins in March and lasts in September with a prolonged dry season between October and February. The geology of the study area is rather complicated and characterized by a variety of rocks spanning in age from paleozoic to quaternary. The study area lies close to main road that links Pristina and Mitrovica as well as within study area extends the railway (railway station). This part of the northern Kosovo constitutes one of the main industrial area in Kosovo as well as one of the most important mining district of Europe. In Mitrovica is located a huge mine named Trepça and could be concluded that there is a big industrial region. Because of this, there are two mining tailings (Kelmend and PIM), thus there is a high level presence of heavy metals in environment. Both of them covered an area of 60 hectares or 0.6 km^2. In the study area has been included 10 groundwater samples (wells) which have been taken in different sites, depth and elevation. All the wells included in the study mainly have been used for drinking purposes.

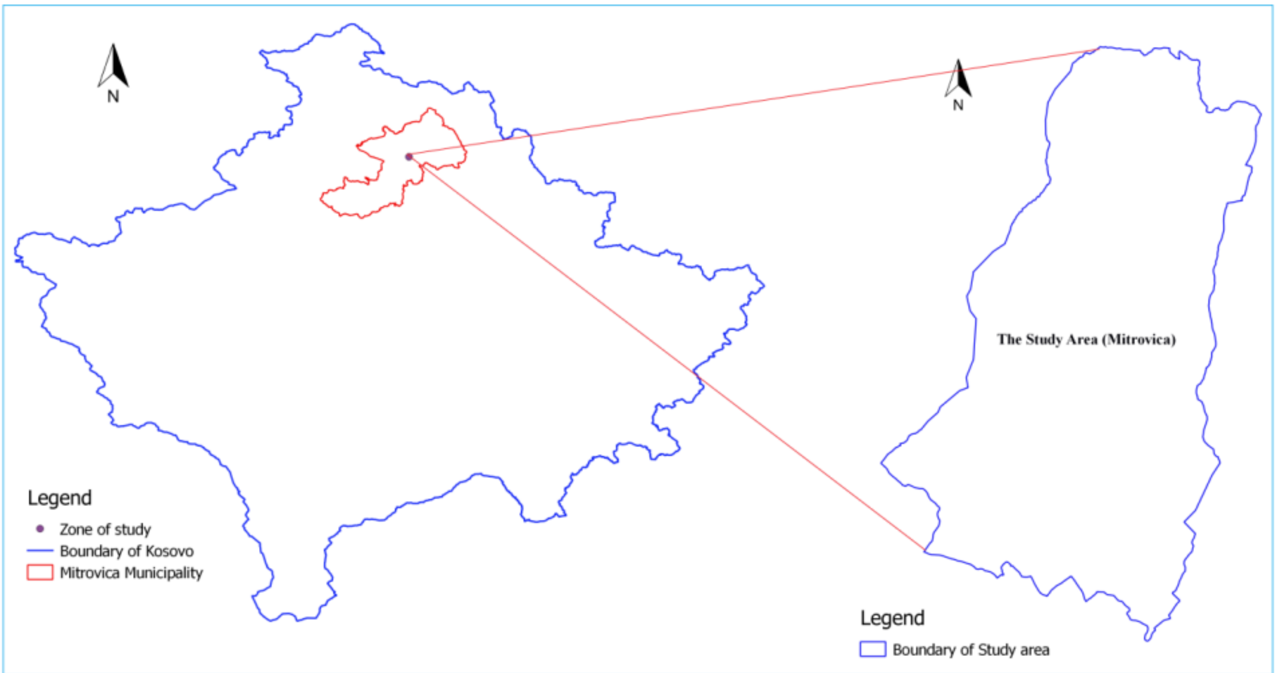

Figure 1. Map of study area

4. Methodology

Two pollution indices were considered in order to compute groundwater quality in terms of heavy metal concertation. These indices are well known in worldwide and their principles are presented in the next sub-chapters.

4.1. Heavy metal pollution index (HPI)

Heavy Metal Pollution Index (HPI) is also a powerful technique for the assessment of water quality on the basis of heavy metal concentration (Balakrishnan and Ramu, 2016). Heavy metal Pollution Index (HPI) has been developed and formulated as (Mohan et al., 1996):

$$HPI = \frac{\sum_{i=1}^{n} WiQi}{\sum_{i=1}^{n} Wi} \qquad (1)$$

$$Q_i = \sum_{i=1}^{n} \frac{|Mi-Ii|}{Si-Ii} \times 100 \qquad (2)$$

where, Q_i is the sub-index of the i^{th} parameter; W_i is the unit weightage of the i^{th} parameter; n is the number of parameters; M_i is the monitored value of heavy metal of i^{th} parameter; I_i is the ideal value of i^{th} parameter; Si is the standard value of the i^{th} parameter.

4.2. Metal index (MI)

The Metal Index (MI) was preliminarily defined by Tamasi and Cini (Tamasi and Cini, 2004). This index can be expressed by the following equation:

$$MI = \sum_{i=1}^{N} \frac{Ci}{(MAC)i} \times 100 \qquad (3)$$

Where MI is the metal index, C is the concentration of each element in solution, MAC is the maximum allowed concentration for each element, and the subscript i is the i^{th} sample.

In the present study, HPI and MI have been computed according the above mentioned methodology and formulas.

4.3. Source data

The present paper were conducted by primary and secondary data. The primary data were considered data which were captured directly from the environment e.g. groundwater samples, samples location, etc. As well as the secondary data were considered data which are not captured directly from the environment e.g. chemical samples analysis, hydrology, DEM, etc. According another categorization in the study have been used mainly two kind of source data: spatial data (position of monitoring stations) and non-spatial data (tabular and attributes data).

The groundwater samples were collected in the May 2018 from 10 wells in Mitrovica region.

The groundwater samples were taken in correlation and full accordance with the EN ISO/ CEI 17025 norms. As well as the conservation of samples were done according the procedure of conservation refer to American Public Health Association 2005 (APHA, 2005). The measurement of heavy metals presence in groundwater samples was done in accordance with the EPA-3015 methods whereas their reading was made in full accordance with EPA-6010C method. In the groundwater samples were determined the degree of concentration of the As, Cr, Cu, Ni, Pb, Zn and Cd. The degree of concentration of the mentioned metals was monitored in Trepça Laboratory by applying the SAA-F technique.

From the Kosovo Cadastral Agency (KCA), the cadastral zones boundaries and the municipality boundary in shapefile, have been used. The mining tailings boundaries were obtained from Ministry of Environmental and Spatial Planning (MESP) in Kosovo as shapefile as well. Transportation and hydrology data (main roads, railway and rivers) in vectorial format were downloaded from Open Street Map (OSM). To map the location of each groundwater sample was used GPS equipment (Leica) based on KOPOS (Kosovo Positioning System) as part of GNSS (Global Navigation Satellite System) family. In the field was captured the position (Y, X coordinate and h (ellipsoidal height)) of groundwater samples determined by GPS. Based on non-spatial data, respectively laboratory results, have been calculated the HPI and MI by applying in Excel of the known formulas (Eq.1, Eq. 2, Eq. 3). In the below table (Tab. 1) has been listed source data used in the study.

Table 1 The source data

Data	Source	Format	Type	Description
Study area	Kosovo Cadastral Agency	Shapefile	Polygon	Boundary
Mining tailings	Ministry of Environment and Spatial Planning	Shapefile	Polygon	Boundary
Grundwater samples	Captured in the Field	Excel format	Point	Y, X, h
Heavy metal samples	Trepca laboratory	Excel format	Textual Numeric	As, Cr, Cu, Ni Pb, Zn, Cd
Chemical analysis	Calculated	Excel format	Textual Numeric	HPI and MI
Transportation	Open Street Map	Shapefile	Line	Roads Railway
Hydrology	Kosovo Cadastral Agency	Shapefile	Line	Rivers
DEM	Advanced Land Observing Satellite (ALOS)	GeoTIFF	Cells	20m

4.4. Data processing

Data derived from different sources as a result of the characteristics of source systems had different structures and formats (Idrizi et al., 2018). Thus, the first step was data harmonization process by conversion into an identical format and reference system as well.

Topological modeling is one of the main steps of data processing, within which the real natural geometric links between the objects are established by defining their relative position (Idrizi et al., 2018). The topological modelling were established between features in order to improve data consistency and facilitate data validation process as well. The source data have been processed and modeled in QGIS software version 2.18. and the output data such as thematic layers with attribute data and cartographic output (thematic maps) including here raster datasets were computed in this software. The ArcCatalog of ArcGIS desktop was used to develop, organize and manage the spatial database (geodatabase) derived from the specific intention of the paper. In ArcCatalog was organized the content of the Groundwater Monitoring spatial database in which were included the thematic datasets (Fig. 4). In the process of designing spatial database, three key models including conceptual, logical and physical model provide guidance to develop a dynamic spatial database. Therefore, the Unified Modeling Language (UML) visual paradigm was used for developing the conceptual, logical and physical model of the spatial database (Fig. 2) in the present study. Numerous calculations were done in Excel by applying formulas from equation 1, 2 and 3. Spatial analysis and interpolation techniques were used in QGIS software to find out the spatial behavior of Heavy Metal Pollution Index and Metal Index in the groundwater monitoring stations. The various thematic layers using a spatial interpolation technique through Inverse Distance Weighted (IDW) and Spline were performed. Groundwater monitoring maps classification for HPI and MI from thematic layers based on WHO standards for drinking water have been created for Mitrovica region, Kosovo. In the study was used KosovaRef01 reference system, an official Kosovo coordinate system. The parameters of Kosovo coordinate system (KosovaRef01) are given in the Table 2.

Table 2 Parameters of KosovaRef01 (Adapted by Maliqi and Penev, 2018)

NAME	KOSOVAREF01
Datum	ETRS89
Ellipsoid	GRS80
Map projection	Gaus-Krugger
Prime meridian	Greenwitch
Central meridian	21°E
Scale factor	0.9999
False easting	7 500 000 m
Prime parallel	Equator
False northing	0 m
Origin of heights	Trieste - Molo Sartorio

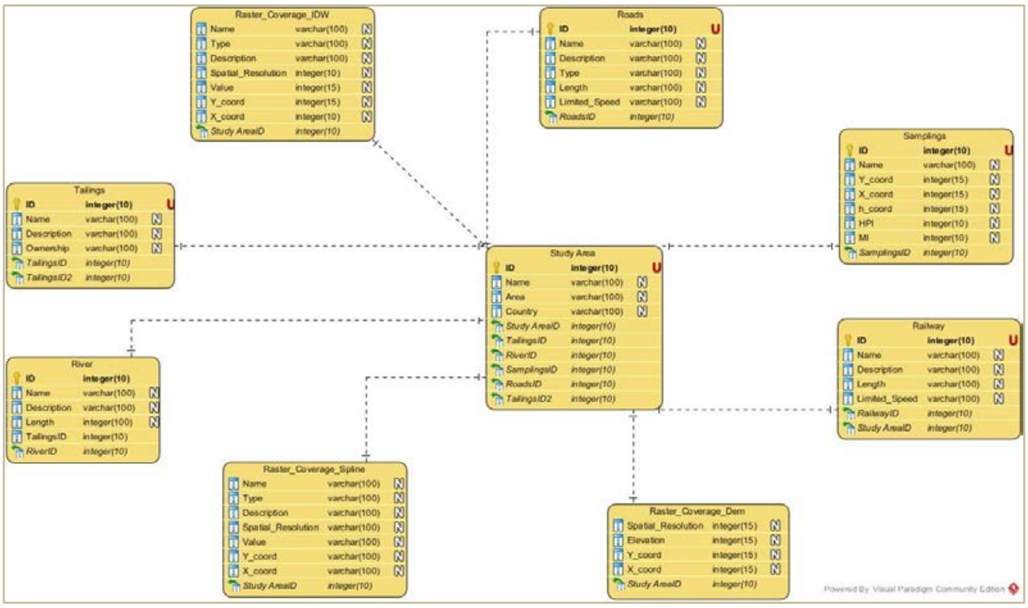

Figure 3. Conceptual model of datasets into spatial database.

5. Data modelling

5.1. Database structure and thematic layers

A database is any information collected and organized into groups (Maliqi et al., 2015). In the spatial database were included: datasets (vector and raster), feature classes, tabular and attribute data, topological rules and spatial reference system. The datasets were defined and established including: transportation and hydrology, groundwater monitoring stations, HPI and MI raster datasets by IDW and Spline interpolation and DEM. Feature classes were defined in each dataset according in the type of representation. The spatial data type such as point, line and polygon of feature classes were determined according to the data content and were stored in the spatial database. The feature classes were utilized to create the graphical content of the Mitrovica region. The tabular and attribute data represent the features attributes and data description, the feature classes were populated with groundwater pollution data and data description as shown in figure 3.

The topological rules were established between features in order to improve data consistency and facilitate data validation process. Defining geometrical link between objects means the phase of topological control and elimination of errors from the mapping phase (Idrizi et al., 2018). Kosovaref01 reference system is used for the spatial database and thematic layers. A numerous thematic layers have been created and developed in the present study. They were grouped and classified in different datasets and feature classes. All thematic layers were included into database entitled “Groundwater Monitoring’. Spatial database consists of six feature datasets including vector and raster datasets. The feature classes have been populated with attribute data as chemical analysis, 3D coordinates, feature classes description and calculated data. Spatial database and groundwater monitoring maps were developed and compiled in official Kosovo reference coordinate system, known as KOSOVAREF01. The spatial database and feature classes are shown in figure 7.

Thematic layers were identified according to the feature types listed in the table 3 and table 4. Each thematic layer will be used in terms of map use, data source, spatial relationship, map scale and symbology. According example below (Tab. 3 and Tab. 4) were developed each vector and raster thematic layer in the Figure 5.

No	Sampling	Y	X	h	ph	Municipality	Settlement	ıi (As)	ni (Cr) r	ri (Cu) n	ł (Ni) r	ıi (Pb)	ı (Zn)	umi (Cd	HPI	MI
1	WS1	7494029.868	4755576.835	858.225	7.62	Mitrovica	Stan Terg	0.024	0.014	0.0445	0.011	0.042	0.071	0.0021	33.012	0.297
2	WS2	7491580.853	4755514.273	839.475	7.3	Mitrovica	Rahova	0.025	0.015	0.0562	0.012	0.079	0.03	0.0003	25.367	0.387
3	WS3	7490646.54	4753428.147	685.411	7.03	Mitrovica	Rahova	0.025	0.012	0.0502	0.017	0.312	0.06	0.0015	95.784	1.075
4	WS4	7489576.098	4752607.95	574.546	7.14	Mitrovica	Kelmend	0.026	0.012	0.0564	0.015	0.05	0.039	0.0058	58.964	0.771
5	WS5	7491093.766	4749771.232	568.251	6.15	Mitrovica	Shupkovc	0.028	0.013	0.0626	0.013	0.123	0.18	0.0037	63.647	0.569
6	WS6	7491943.153	4751399.502	602.776	6.62	Mitrovica	Reka	0.027	0.014	0.0544	0.016	0.178	0.054	0.0044	81.578	0.743
7	WS7	7492390.966	4747340.661	550.432	7.37	Mitrovica	Shupkovc	0.028	0.01	0.0653	0.017	0.316	0.037	0.0077	135.3	1.18
8	WS8	7489662.439	4747810.383	554.987	7.2	Mitrovica	Tavnik	0.024	0.011	0.0801	0.012	0.061	0.087	0.0048	53.646	0.389
9	WS9	7488007.494	4749086.504	599.442	7.56	Mitrovica	Zhabare	0.027	0.09	0.047	0.011	0.08	0.028	0.0059	85.365	0.686
10	WS10	7488615.382	4748065.389	539.432	7.56	Mitrovica	Shipol	0.023	0.011	0.0546	0.012	0.138	0.29	0.0055	76.72	0.615

Figure 4. Tabular and attribute data of feature class (monitoring stations)

Table 3 Specifications of vector thematic layers.

Layer	**Specifications**	**Description**
Study Area	Map use	Show study area boundary
	Data source	Vector file from KCA
	Representation	Polygon
	Map scale	Visible at all scales
	Symbology	Polygon without fill color

Table 4 Specifications of raster (interpolation) thematic layers.

Layer	Specifications	Description
IDW Interpolation	Map use	Show HPI and MI distribution
	Data source	Groundwater monitoring stations
	Representation	Raster
	Map scale	Visible at all scales
	Symbology	Raster multicolor classified

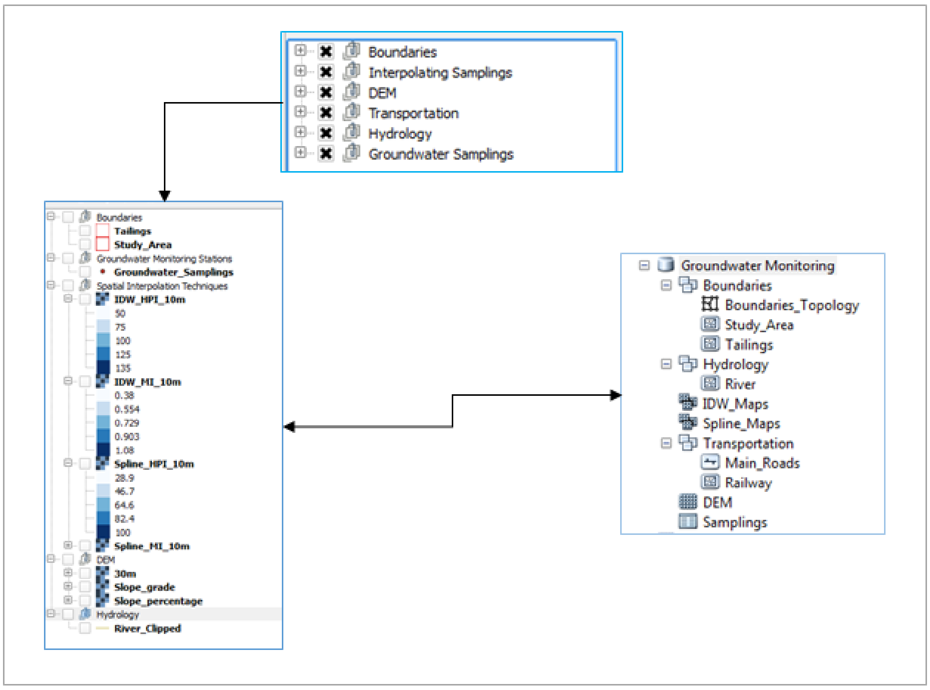

Figure 5. Datasets (vector and raster) & Grouped and classified key thematic layers and Spatial database with datasets.

Datasets are utilized to group the feature classes that share spatial reference, spatial relationship and topologies in the 'Groundwater Monitoring' database. The spatial database were proposed according to the mentioned specifications for the groundwater monitoring in Mitrovica region. The groundwater monitoring data were loaded into the spatial database. Figure 6. illustrates the structure of the spatial database developed in the present study.

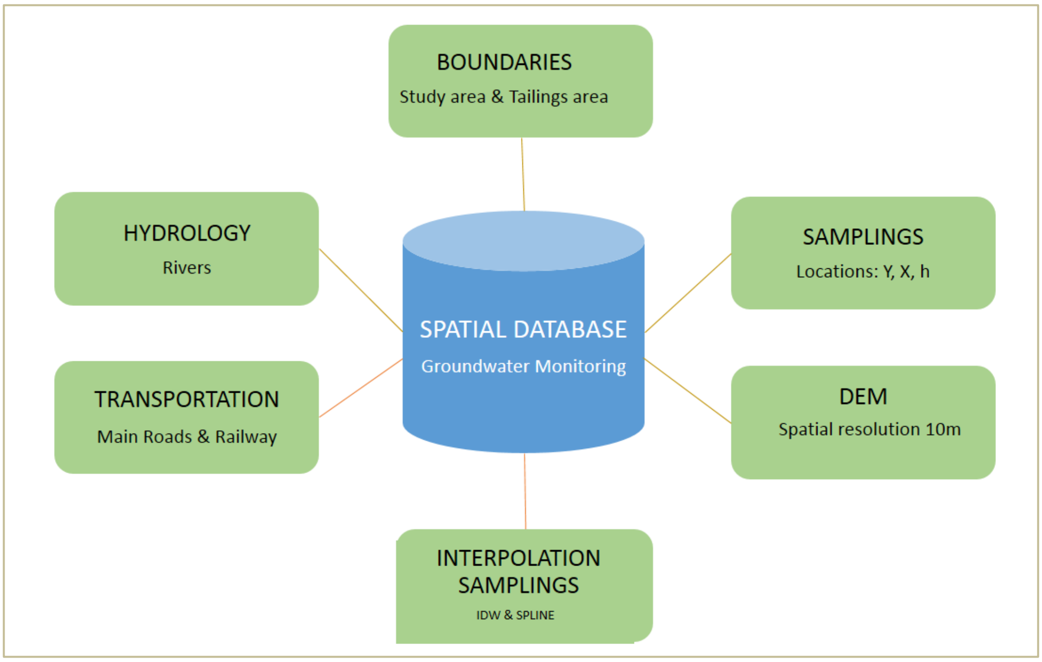

Figure 6. Structure of spatial database and datasets

6. Spatial interpolation and thematic maps

6.1. Interpolation techniques and their accuracy

In general, spatial interpolation techniques can be classified in two main groups: (1) mechanical or non-geostatistical technique and (2) geostatistical technique. The IDW and Spline interpolation techniques fall into mechanical or non-geostatistical technique. The spatial resolution to produce raster maps was chosen 10m spatial resolution and it was selected during the interpolation process into GIS environment. The heavy metal pollution indices in the groundwater does not change rapidly within a small area therefore can be conclude that 10m spatial resolution has been very appropriate spatial resolution. In order to visualize the groundwater monitoring maps were used two interpolation techniques (IDW and Spline) supporting by QGIS software. The interpolation techniques help to assessment and monitor values for unknown point and create a continuous surface dataset of the spatial distribution. The range values in two techniques differ from each other. In general, authors have estimated that two of them are very appropriate techniques for spatial interpolation and they give us valuable results. Thus, in the study have been evaluated which is the best fitted interpolation techniques (IDW and Spline) according commonly used indices, such as Mean Squared Error (MSE) and Root Mean Squar Error (RMSE). For *n* observations, *p* predicted value and *o* observed value these indices are evaluated using the expressions below (Ikechukwu et al., 2017):

$$MSE = \frac{1}{\mathrm{n}} \sum_{i=1}^{n} (p_i - o_i)^2 \quad (4)$$

$$RMSE = \left[\frac{1}{\mathrm{n}} \sum_{i=1}^{n} (p_i - o_i)^2\right]^{1/2} \quad (5)$$

The above methodology (Eq. 4 and Eq. 5) have been used to rank the spatial interpolation techniques, used in the present study. In this way was determined the accuracy of interpolation techniques and the present study has demonstrated that Spline interpolation technique produced the lowest MSE and RMSE from the observed to the predicted values, as is shown in table below Table 5. Thus, the obtained results in Table 5 have demonstrated that Spline technique has been more fitted technique than IDW technique.

Table 5. The ranking of spatial interpolation techniques.

Technique	IDW	Spline
MSE	0.35	0.32
RMSE	0.58	0.57
Rank	**2**	**1**

6.2. Compilation of groundwater monitoring maps

The compilation of groundwater monitoring maps has been one of the main objectives of the present study. Thus, after have been developed the spatial database, with feature classes and spatial interpolation techniques, has been realized the process of compilation groundwater monitoring maps (HPI maps and MI maps). The mathematical elements of maps were calculated and were compiled as cartographic output of the study 4 maps by using QGIS software tools. The compiled thematic maps for groundwater monitoring represents the situation of May 2018. The list of groundwater monitoring maps in the present study is as follow:

- Heavy Metal Pollution Index (HPI) map by IDW interpolation (Fig. 7).
- Metal Index (MI) map by IDW interpolation (Fig. 7).
- Heavy Metal Pollution Index (HPI) map by Spline interpolation (Fig. 8).
- Metal Index (MI) map by Spline interpolation (Fig. 8).

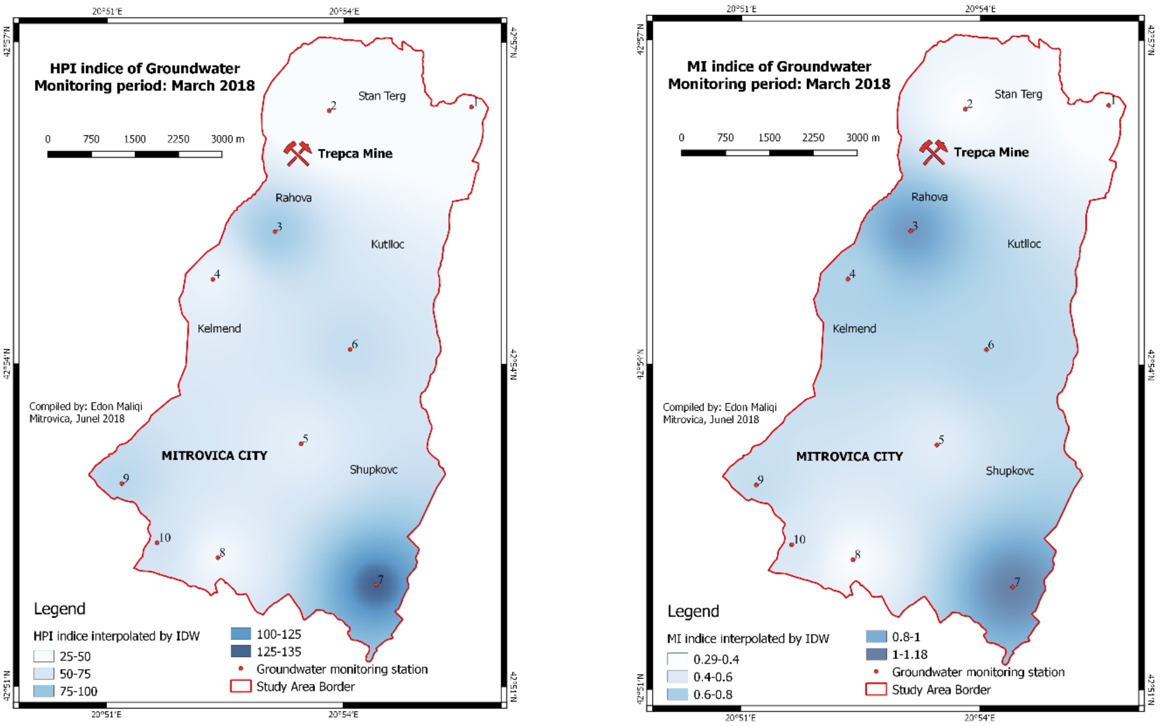

Figure 7. Thematic maps of HPI and MI by IDW technique.

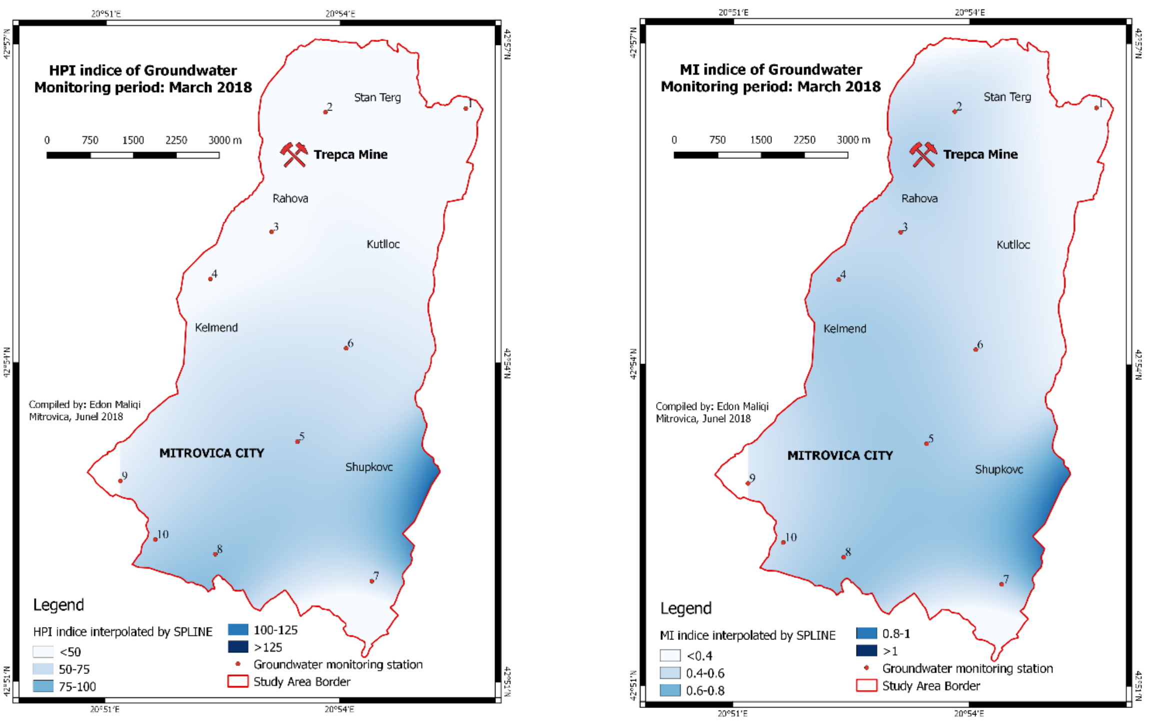

Figure 8. Thematic maps of HPI and MI by Spline technique.

7. Conclusions

Spatial distribution of groundwater pollution maps were carried out through GIS technology. The study has been demonstrated that GIS technology is very useful system for environmental monitoring and assessment as well as in environmental management. Having spatial data and attribute data as a one system help us to show spatial distribution and pollution values of HPI and MI. The study has shown that spatial interpolation methods as IDW and Spline help us for better management groundwater pollution. The study presents that GIS technology is an effective tool for developing of various spatial database, thematic layers and maps showing the spatial distribution of groundwater pollution maps. Moreover, GIS technology makes the groundwater pollution maps in easily understand format.

From the methodological point of view, the study presents that GIS technology is very useful for developing of the spatial database and compilation the series of the groundwater monitoring maps for Mitrovica region. The spatial and non-spatial results performed in the study can be compared easily with national and international standards and directives.

The series of thematic maps compiled in the present study, can be used in the next studies as zero series maps in the groundwater monitoring and assessment in the Mitrovica region. From the groundwater monitoring maps easily could be compared the level of pollution in groundwater drinking based on WHO standards and it could be visualized according to the latest updating information. However, from the groundwater monitoring maps of HPI could be concluded that is just a sample from ten entirely that passed the critical value of 100, so there was just a site polluted above the permissible value or there is just a well than can not be used for drinking. As well as from MI maps could be concluded that 8 samples were categorized in ‘Class II’ of pollution or the pollution was ‘Pure’. It could be concluded that the main source of groundwater pollution in Mitrovica region remains mining tailings. The study has demonstrated mining tailings effect in surrounding groundwater. Thus, in order to prevent environmental pollution in general as well as groundwater pollution in particular, will be immediate issue addressing of concerns for mining tailings in Mitrovica. The situation presented in the study, authors hope that will help local and central institutions and enterprises for making decision and environmental policy making as well.

As well as the study has shown that the best spatial interpolation technique have been produced the least error as measured by MSE and RMSE. It has demonstrated that Spline technique has had the lowest MSE and RMSE. Thus, it was ranked as the most fitted spatial interpolation technique compared with IDW technique.

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References

[1] Abdullah, J., 2013. Quality assessment for Shatt Al – Arab River using heavy metal pollution index and metal index. J. Environ. Earth Sci. 3(5), 114-120.
[2] Adaikpoh, E., Nwajei, G. and Ogala, J., 2005. Heavy metal concentrations in coal and sediments from River Ekulu in Enugu Coal City of Nigeria. J. Appl. Sci. Environ. Manag. 9(3), 5-8.
[3] Akoto, O., Bruce, T. and Darko, G., 2008. Heavy metal pollution profiles in streams serving the Owabi reservoir. African J. Environ. Sci. Tech. 2(11), 354 - 359.
[4] American Public Health Association, 2005. Standard methods for the examination of water and wastewater. 21st Edition, New York, American Public Health Association.
[5] Balakrishnan, A. and Ramu, A., 2016. Evaluation of Heavy Metal Pollution Index (HPI) of Ground Water in and around the Coastal Area of Gulf of Mannar Biosphere and Palk Strait. Journal of Advanced Chemical Sciences 2(3) 331 – 333.
[6] Ferry, T., Akihiko, K. and Asal, M., 2003. A conceptual Database design for hydrology using GIS. In the proceedings of Asia Pacific Association of Hydrology and Water Rsources, Japan, Kyoto.
[7] Horton, R., 1965. An index number system for rating water quality. Jour. Water Poll. Cont. Feder. 300-305.
[8] Idrizi, B., Sulejmani, V., and Zimeri, Z., 2018. Multi-scale map for three levels of patial planning data sets for the municipality of Vitia in Kosova. 7th International Conference on Cartography and GIS, 18-23 June 2018, Sozopol, Bulgaria.
[9] Ikechukwu, M, Ebinne, E., Idorenyin, U. and Raphael, N., 2017. Accuracy Assessment and Comparative Analysis of IDW, Spline and Kriging in Spatial Interpolation of Landform (Topography): An Experimental Study. Journal of Geographic Information Systems. 354-371.
[10] Khan, F., Husain, T. and Lumb, A., 2003. Water quality evaluation and trend analysis in selected watersheds of the Atlantic Region of Canada. Environmental Monitoring and Assessment.
[11] Maliqi, E. and Penev, P. 2018. Monitoring of vegetation change by using RS and GIS techniques in Mitrovica, Kosovo. Journal of Cartography and Geographic Information Systems. Volume 1. Issue 1. 1-13.
[12] Maliqi, E. and Penev, P., 2018. Using of Digital Elevation Model in the geological exploration in Kosovo. 7th International Conference on cartography and GIS. Sozopol. Bulgaria.
[13] Maliqi, E., Hyseni, D. and Maliqi, G., 2015. Application of GIS In the special zone of interest "Gumnishtë" – Kosovo. Micro, Macro & Mezzo Geoinformation. No. 4, 49-59.
[14] Mohan, S., Nithila, P. and Reddy S., 199). Estimation of heavy metal in drinking water and development of heavy metal pollution index. J. Environ. Sci. Health A 31(2), 283-289.
[15] Raikar, R. and Sneha, K., 2012. Water quality analysis of Bhadravathi taluk using GIS – a case study. International journal of environmental sciences volume 2, no 4.
[16] Reddy, S., 1995. Encyclopedia of environmental pollution and control. Volume 1. Enviro. media, Karada, Apple Academic Press, Inc., India.
[17] Reza, R. and Singh, G., 2010. Assessment of ground water quality status by using Water Quality Index method in Orissa, India. World Appl. Sci. Jour. 9(12), 1392-1397.
[18] Rizwan, R., Gurdeep, S. and Manish, J., 2011. Application of heavy metal pollution index for ground water quality assessment in Angul District of Orissa, India. Int. J. Res. Chem. Environ. 1(2), 118-122.
[19] Rokbani, M., Gueddari, M. and Bouhlila, R., 2011. Use of Geographical Information System and Water Quality Index to Assess Groundwater Quality in El Khairat Deep Aquifer (Enfidha, Tunisian Sahel). Iranica Journal of Energy & Environment 2 (2).

[20] Sargaonkar, A. and Deshpande, V., 2003. Development of an everall index pollution for surfacewater based on a general classification scheme in Indian context. Environmental Monitoring and Assessment.
[21] Sirajudeen, J., Arulmanikandan, S. and Manivel, V., 2014. Heavy metal pollution index of ground water of Fathima Nagar area near Uyyakondan Channel Tiruchirappalli District, Tamilnadu, India. World J. Pharm. Pharmaceut. Sci. 4(1), 967-975.
[22] Tamasi, G. and Cini, R., 2004. Heavy metals in drinking waters from Mount Amiata (Tuscany, Italy) Possible risks from arsenic for public health in the province of Siena. Sci. Total Environ. 41-51.
[23] Tiwari, T. and Misra, N., 1985. A preliminary assignment of Water Quality Index to major Indian rivers. Indian J. Environ. Protec. 5(4), 276-279.