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Full Length Research Paper

Zoning cyanide concentration of village springs nearby gold extraction plants in Takab city by geographical information system (GIS)

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As the main sources of water supply to the villages are springs, this study evaluated cyanide concentration of village springs nearby the Agh-Darreh and Zarehshuran gold extraction plants in Takab city in 2011 and zoned it by geographical information system (GIS). Mean water temperature, pH, Electrical conductively, total dissolved solids, salinity and cyanide content of studied springs was 14.89±2.482 °C, 7.38±0.368, 656.3±397.45 µs/cm, 319.135±199.34 mg/l, 0.32±0.199% and 0.004± 0.0017 unit, respectively. Except cyanide concentrations the other parameters value in studied springs had significant different ($P<0.05$) than what. Correlation analysis showed the concentration of cyanide in the springs water sample and the distance from gold extraction plants has a significant reversed relationship ($P<0.0001$and $r = -0.72$). As obtained results showed those springs are closer to the gold extraction plants has more Cyanide in water samples. The use of GIS is very useful to explain the results visually as a picture. GIS can show results integrated and clearly, so it is understandable for non-expert person.

Keywords: Spring, Cyanide, Geographical Information System, Gold Extraction Plants, Takab

INTRODUCTION

The Study water resources potential in Iran shows that Groundwater comprises about 30 percent, while the share of groundwater in total water consumption is excess of 50%. In many cases, changes in the pollution and chemical quality of ground water can be seen in industrial areas especially today. Groundwater Contamination commonly occurs when Soluble or insoluble substances resulting from human activities are imported to ground water or buffer resources (Shokoohi et al., 2011, Shokuhi et al., 2011). The quality of groundwater has been affected by natural deposits and geological formations and there is a different quality. High concentrations of these substances in water consumption may limit its potential for drinking. The Identify qualitative changes, groundwater and areas pollution it is of particular importance in management of groundwater quality control. Developing an action plan for continuous monitoring of quality changes over time is inevitable. Iran is a developing country and its development has forced the expansion of mines and mineral processing plants. Therefore, for sustainable development of this industry is necessary to can be identified aspects of their

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environment (the climate of the country). Because of mining tailings and mineral processing industry is one of the main sources of environmental problems and it is Including one of the most important problems of cyanide compounds in the aquatic environment. Measured of the cyanide compounds and compared with international standards in the water sources Due to the exposure of humans to cyanide spilled into surface water and groundwater in the area is necessary. Cyanide and compounds are used for extracting valuable metals such as gold from low-grade ores. May be can use other compounds but cyanide using has economic advantages. Cyanideation due to availability, low cost and high capacity in isolation, as it is considered the is the most common method used in the leaching of gold from the ore. Along with the increasing use of cyanide in mining, this article has been important the Discusses issue of environmental organizations and governments (Huertas et al., 2010, Shafaei et al., 2008). The term of cyanide, is formed an anion with a negative charge is applied to a carbon atom and a nitrogen atom that is connected by a triple bond. As well as inorganic and organic compounds containing the group-CN is known Cyanide (Abdalla et al., 2010, Dash et al., 2009). Different plants, some bacteria in soil and samples of invertebrates can produce cyanide naturally. However, the amounts of cyanide compounds are found in nature rarely that harmful to the environment (Dash et al., 2009, Moussavi et al., 2011). Cyanide also tends to react with many chemicals and has produced a wide range of toxic compounds. This is due to the presence of carbon (an organic compound) in the structure of cyanide that is combined with other carbon compounds like organisms easily (Dash et al., 2009). Species of cyanide are classified based on physical and chemical properties to free cyanide, simple cyanide compounds, cyanide complexes, cyanides, cyanogen chloride and thiocyanate. Cyanide is very toxic substance and can be dangerous for humans. Gas or liquid and alkali salts of hydrogen cyanide may be through inhalation and ingestion into the body also are absorbed through the skin and eyes. According to the World Health Organization and the Institute of Industrial Research of Iran, maximum cyanide in drinking water sources is 0.007 mg per liter (Dash et al., 2009, Moussavi et al., 2011). The cyanide can be measured by four method Chemical analysis include free cyanide, cyanide reactive with chlorine, weak acid dissociable and Total cyanide usually (Moussavi et al., 2011). One of three methods determines free cyanide Depending on the concentration of cyanide in the sample and required accuracy: Titration with silver nitrate, ion selective electrode or colorimetric. Free cyanide levels can be control by the pH of the water. Free cyanide more appears in water with a pH 6 to 8 as HCN While the CN-ions are consistent at pH above 9.2 and with decreasing pH these ions are converted to HCN (Dash et al., 2009). Taebi and Colleagues did monitored cyanide Natural degradation in soil in plain Mu'tah, nearby gold mine and mill located in Isfahan in 2002. They concluded that the cyanide concentration decreased in the soil with distance from the source of contamination and increased with increasing soil depth (Taebi et al., 2006). Osman and colleagues investigated the cyanide in gold mining and impact on groundwater in dry areas Yanqul, in Amman in 2010. They concluded that were measured addition of cyanide; heavy metals and cyanide complexes to investigate the potential gold mine in around 16 Piezometers wells. Results showed that with a few years of operation the plant, appropriate structure of tailings dams preventing the entry of contaminants into the groundwater and there isn't where a serious threat for air and soil in these areas (Abdalla et al., 2010). Soldan and colleagues in investigate in the Leakage of cyanide in the tailings dam gold extraction plant in Romania was conclusion those Approximately 100,000 cubic meters of cyanide toxic waste has leaked into local rivers. This led to have been the premature death of aquatic organisms and phylogenies living near the river (Soldán et al., 2001).

There is a two gold extraction plant with names are Pouya Zarkan Agh-Darreh and Zarehshuran Pars kani in 32 km north of the Takab city in West Azarbaijan Province. The first one will be operated about 8 years old and the second plant for about 4 years. This plant is used the Tailings dams for the collection and maintenance of the plant effluent and waste materials from the mineral concentrate. These dams and the leaks of toxic substances such as cyanide and its compounds have adverse effects in groundwater and surface water quality, public health, plants, animals and soil. Dam failure due to broken and contamination from toxic influence is one of the main reasons for environmental problems(Soldán et al., 2001). According to the two companies, the process of extracting gold from ore from the mine are performed using a solution of sodium cyanide after the crushing and leaching operations. During this stage, the gold cyanide solution and the solution are solved and the made effluent flows Evacuated into the tailings dams.

The Large volumes of Pouya Zarkan Agh-Darreh plant effluent by PPSM (Paste Production and Storage Mechanism) system is accumulated inside the factory on steep terrain as paste sludge. Sodium cyanide used in factory production lines and 800 grams per ton of ore. Sodium cyanide used in factory production lines is 800 grams per ton of ore and Feed two gold extraction plants is 2000 tons of ore per day approximately. In that case, the amount of sodium cyanide consumption will be 1600 pounds per day (Taebi et al., 2006). Cyanide consumption and production in place was one of the main reasons checking for the pollution of drinking water in villages around the factory that those Springs are main sources of provides water the villages. With regard to have been reported the leaking of cyanide tailings dam wall has broken several of them. In addition, factors are implicated in broadcasting of cyanide around the factory

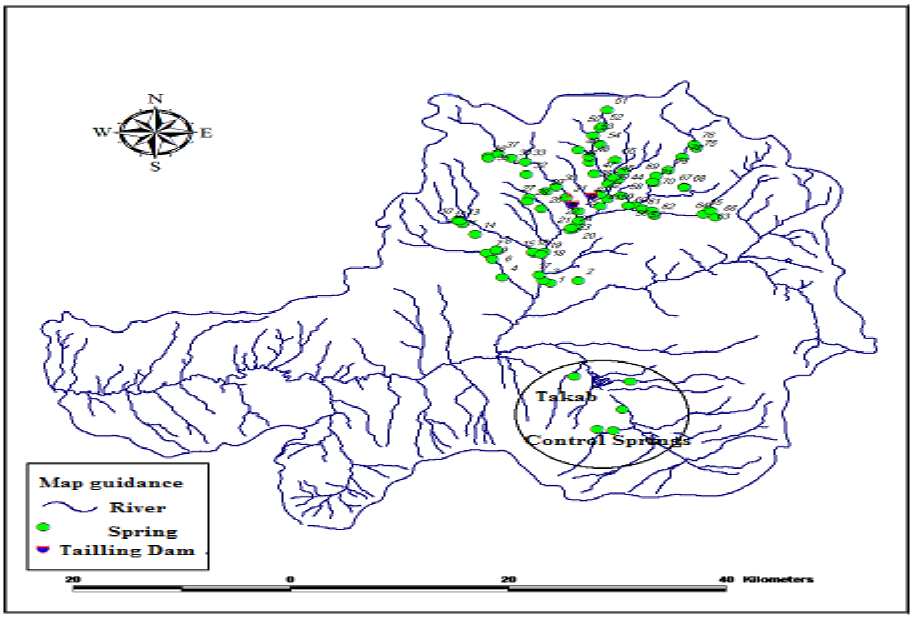


Figure 1: Location of springs and dams gold extraction plant tailings area on the map

such as the wind and the rain overflow tailings dam's contents. There is cyanide contamination of water resources in the region but is unknown intensity of infection due to the lack of research in this area. The purpose of this Study was zoning concentrations of cyanide springs villages around Agh-Darreh and Zarehshuran gold extraction plants in Takab city using geographical information system (GIS).

MATERIALS AND METHODS

This study is a cross-sectional study that were monitored water quality the main and sub- springs around the Agh-Darreh Puia Zarkan and pars kani Zarehshuran gold extraction plants. Since the factories are located in Takht-e Soleymān in Takab city, General location of the area was studied using 1/5000 map. Then field monitoring conducted and studies of the local residents, was selected 76 spring water for survey Cyanide the main and ancillary spring constant taking away natural slope of the land and spring from gold factory. Five springs were selected to compare the results to control springs out of the aquifer studies (Figure 1).

According to the project cost and feasibility tests with free cyanide springs, other parameters were measured Using portable devices in place including: temperature, pH, EC, TDS (To determine the amount of salt springs). The samples were transferred for analysis to laboratory of Orumia University of medical sciences. The sampling method used was systematic or regular. Because the quality of spring water may be changes during day with physicochemical, Therefore all samples were harvested at 18 to 20 per day. The Parameters such as temperature, electrical conductivity, total dissolved solids, and pH were measured on site. The electrical conductivity and total dissolved solids using EC meter sension5 model, Water temperature and pH meters using sension1 models were measured that all of which were portable HACH Company. To measure the amount of free cyanide in spring's water samples was used the colorimetric method using DR-5000 device Pyridine-Pyrazalone method (HACH method 8027 provided by the company) (Rahmani et al., 2013). With regard to the various chemicals that interfere with the measurement of cyanide is required that during the sample is known confounders with appropriate methods and if they were to be stabilized. To protect the sample Chlorine used the solution of sodium arsenate, sodium thiosulfate or ascorbic acid with Sulfamic acid. Also to protect the samples containing sulfides was used the lead acetate or lead carbonate (Rahmani et al., 2013). With Identification of the springs in the spring of 2012 by UTM coordinates were recorded using a GPS device and was conducted sampling and analysis in the summer. The data from this study was zoning after analyzing using Arc GIS 9.3 software. Then was drawn the final zoning map as for color distribution of cyanide concentrations in springs. GIS software is capable display the geographic information on of stations on the base map that was recorded by the GPS device. To determine the sample size were selected number of spring's main equal to 31 and sub-springs equal to 87. The main springs there are use as drinking water in villages and water springs have

Table 1: classification study springs according to distance (km) and types of springs

row	Distance from tailings dams(KM)	types of springs	Number of Springs
1	Less than 2 kilometers	A	0
		F	4
2	2.1 to 4 km	A	3
		F	8
3	4.1 to 6 km	A	6
		F	5
4	6.1 to 8 km	A	7
		F	7
5	8.1 to 10	A	3
		F	6
6	10.1 to 12	A	11
		F	12
7	12 km <	A	1
		F	3
	Total Springs	A=31	
		F=45	

Table 2: mean water temperature, pH, TDS, EC, Sal. And cyanide for the springs studied

	The parameters studied (Standard deviation ± mean)					
Number of samples	**CN (mg/l)**	**%Sal**	**EC (µs/cm)**	**TDS (mg/l)**	**pH**	**water temperature (C°)**
76	0.0017 ±0.004	0.199 ±0.32	397.45 ±656.3	199.34 ±319.135	0.368 ±7.38	2.482 ±14.89

been brought into line from the storage resources nearby villages. Sub-springs are those the locals use of the water for doing farm or ranching and used other people who are traveling to the area for recreation. Studied springs (main springs) numbers were determined based on values of N=87, α=0.05, d=0.1, p=0.5 and the following formula.

$$n_0 = \frac{Z^2{}_{1-\frac{\alpha}{2}} pq}{d^2}$$

$$n = \frac{n_0}{(1+\frac{n_0}{N})}$$

In addition, numbers of sub-springs were chosen based on their distance from the mines. Five springs were chosen outside studied the watershed and aquifer as control springs. Whole sample size was 81 springs in this study.

RESULTS

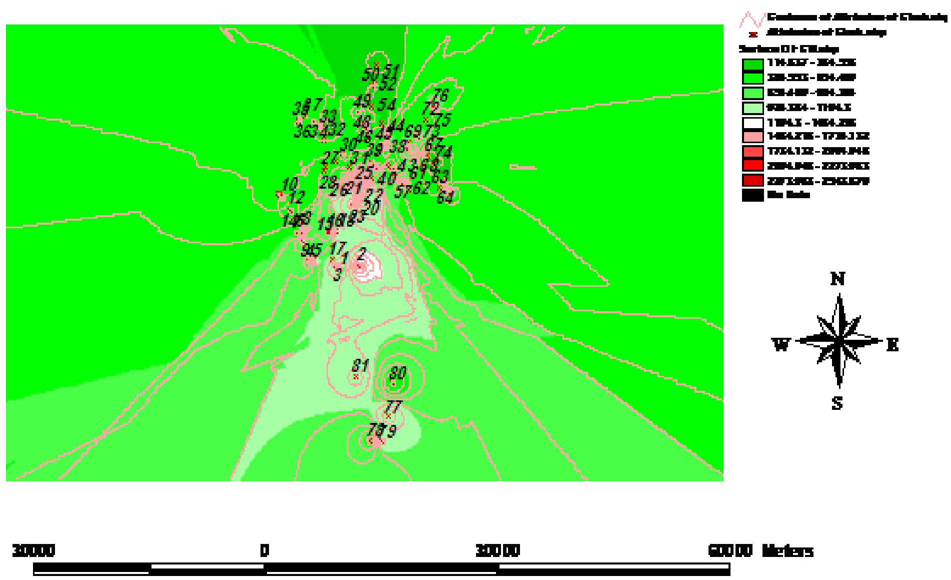
In this study, was determined the springs in the villages of surrounding gold extraction plant and were classified Based on main and sub-springs and distance there from the factory. Springs distance the gold extraction plants were classified into seven categories (Less than 2 kilometers, 2.1 to 4 km, 4.1 to 6 km, 6.1 to 8 km, 8.1 to 10, 10.1 to 12 and More than 12 km). According to Table 1, the maximum number of springs is located in the range 10.1 to 12 km.

For each of the samples the springs were measured 6 parameters including: water temperature, pH, total dissolved solids, Electrical conductivity, Salinity and Cyanide concentration. Maximum Temperature there is (20 C °) in the village of Haji Baba Olya in control spring and the lowest water temperature were (9.6 C °) of the Qinerjh Village Springs. The maximum and minimum values for the parameters pH there is in the Kuse Piri and Nosratabad villages 8.31 mg and 6.73 mg, respectively. The maximum and minimum values for the total suspended solids there is in the Shirmard and Agh-Darreh villages 1309 mg and 54 mg, respectively. The maximum and minimum values for the Electrical conductivity there is in the Shirmard and Agh-Darreh villages (2580 µscm^{-1} and 113 µscm^{-1}), respectively. In addition, the highest percentage of salinity there is in water samples taken from Shirmrd village springs equal to (1.3%). For the cyanide, highest concentration has been identified in samples from village Shirmrd springs (0.009 mg) and the lowest concentration of this parameter exists to control springs (below detection limit). Based on the results, mean of parameters are given in Table 2.

General Stats for each of the parameters are calculated well to separate the sub and main springs studied that including: water temperature, pH, TDS, EC, Salinity and cyanide. Significant differences were studied between

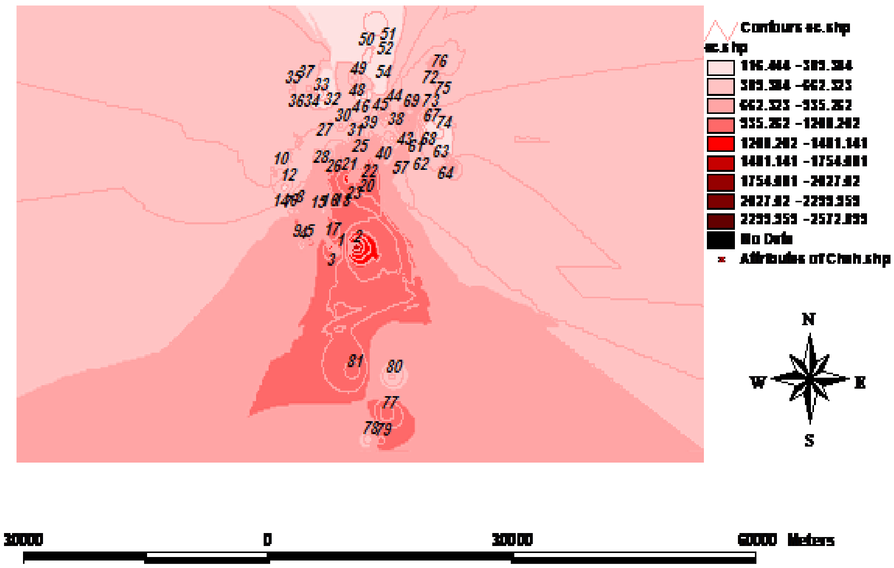
Table 3: relationship between variables in springs water sample together

Variable	Type of statistical test	Distance	Temperature	pH	TDS	EC	Sal	CN
height	The correlation coefficient	0.22	-0.22	0.00	-0.66	-0.66	-0.63	0.00
	Amount of possibility	0.051	0.046	0.973	0.0001<	0.0001<	0.0001<	0.98
distance	The correlation coefficient		0.07	0.05	-0.08	-0.08	-0.06	-0.72
	Amount of possibility		0.521	0.63	0.504	0.463	0.613	0.0001<
temperature	The correlation coefficient			0.27	-0.05	-0.06	-0.06	0.02
	Amount of possibility			0.017	0.628	0.594	0.568	0.876
pH	The correlation coefficient				-0.37	-0.37	-0.36	-0.07
	Amount of possibility				0.001	0.001	0.001	0.555
TDS	The correlation coefficient					1.00	0.98	0.06
	Amount of possibility					0.0001<	0.0001<	0.596
EC	The correlation coefficient						0.98	0.07
	Amount of possibility						0.0001<	0.58
Sal	The correlation coefficient							0.06
	Amount of possibility							0.587

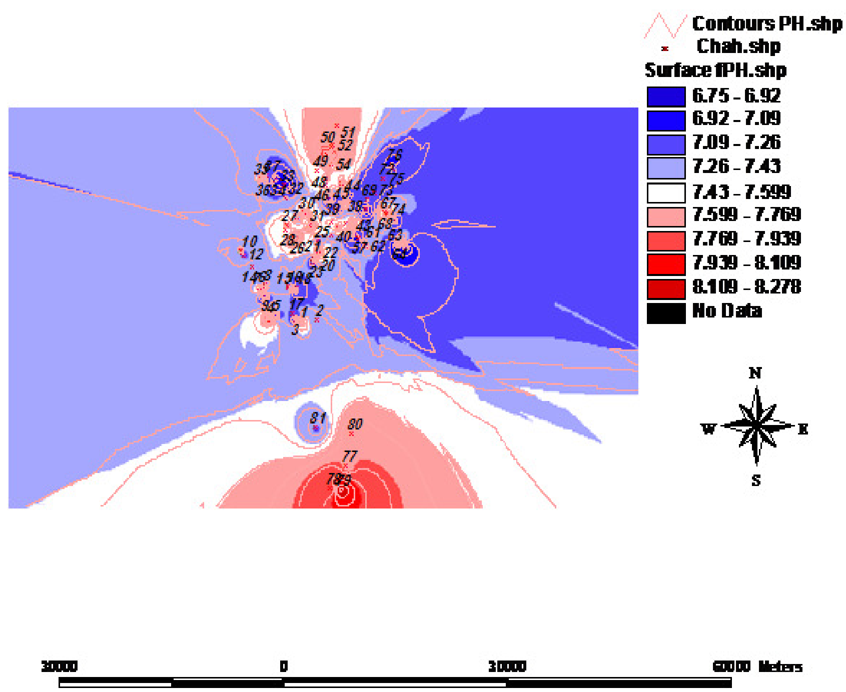


Figures 2: Results cyanide concentration in the samples studied springs using Arc GIS

each of these parameters in springs statistically. Based on the results obtained only difference in the spring of cyanide concentration is not significantly from each other ($p= 0.11$). But were different significant for the other parameters ($p< 0.05$). Also were considered Relationship any of the parameters of the main and control springs. Based on the results there is a significant difference for the parameter pH to main and control springs ($p= 0.016$). Using correlation coefficients were compared Relationship each of the parameters studied with each other that results are presented in Table 3. As is evident in Table, Parameters such as spring's water temperature, total dissolved solids, Electrical conductivity, salinity, and Percent salinity was a significant association of inferential statistics with height above sea level ($p< 0.05$). Cyanide concentrations in springs were significant and reversed with springs distance the gold extraction plants. Means increase in springs distance from gold extraction plant, will decrease concentration of cyanide in water springs. For pH parameter had exist a reverse and significant Relationship with total dissolved solids, Percent salinity and Electrical conductivity. As well as had Existed a direct and significant relationship for total dissolved solids with electrical conductivity of the Percent salinity has a direct and significant relationship. For a more detailed explanation of analysis of springs is used of geographic information system (GIS) and Arc GIS software that results are shown in Figures 2 to 6. According to Figure 2, Cyanide concentration for all springs was in the range 0.004 ± 0.0017 mgl^{-1}. It can be seen in Figure 3, the electrical conductivity of spring's water near gold extraction plant has been most of than studied springs.

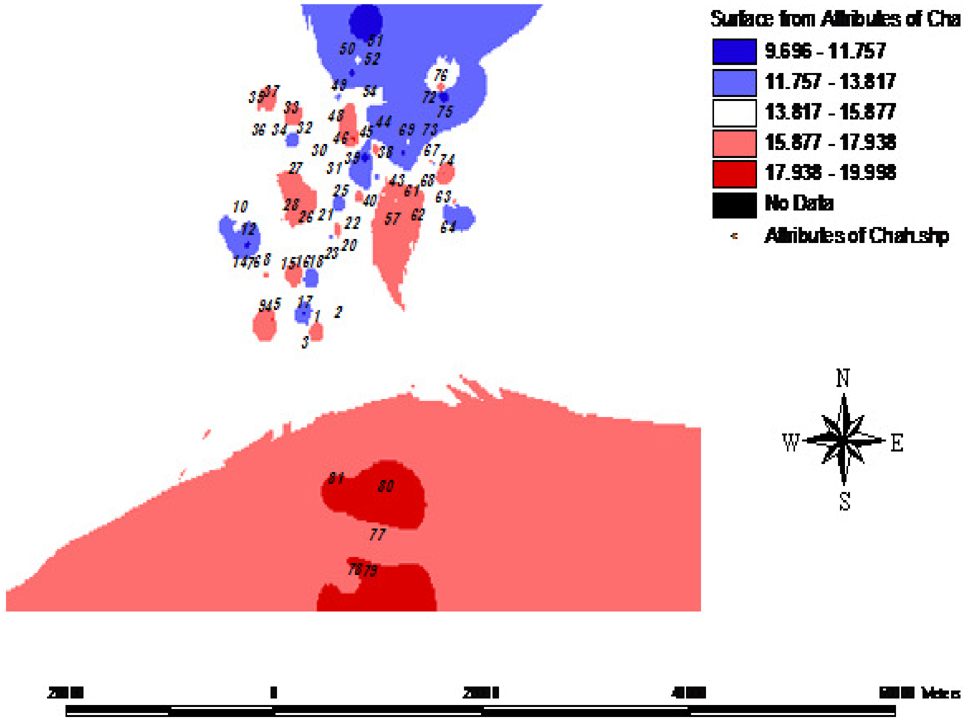


Figures 3: Results electrical conductivity (µscm^{-1}) in the samples studied springs using Arc GIS

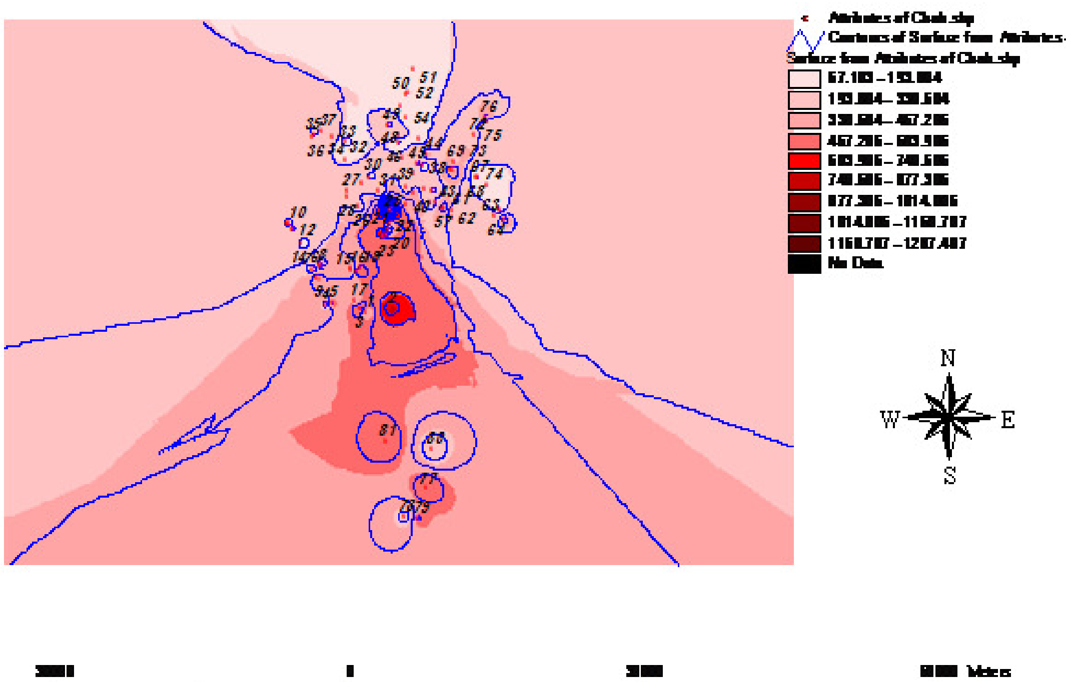


Figures 4: Results pH in the samples studied springs using Arc GIS

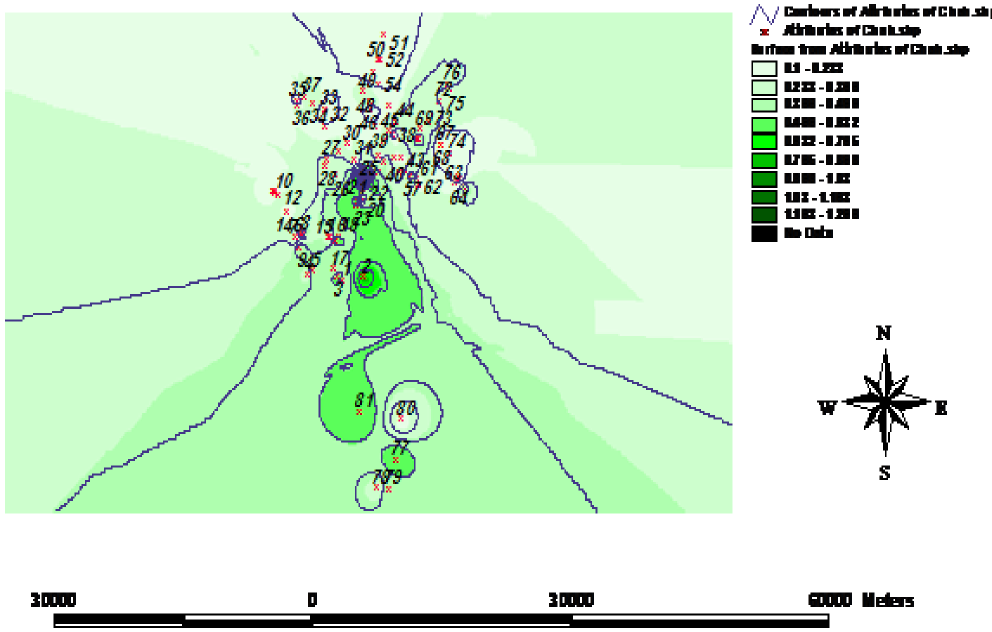
According to Figure 4, the pH of the spring water is in the ranges of 7 to 8. According to Figure 5, Water temperatures have been in most of the studied springs in range Means 14.89 C °. As it is evident from Figure 6, TDS levels in most water springs has been less than 319.13 mgl^{-1} but for control springs nearer to the gold production plant has been higher than mean. According to Figure 7, except springs near the gold extraction plant, salinity values less than main (0.32%) that is the similar to pattern TDS concentration. As well as Concentration of cyanide in the studied springs in comparison the position of the gold extraction plant is shown in Figure 8. The concentration of cyanide classification in the springs is presented below using Arc GIS software. As it is evident



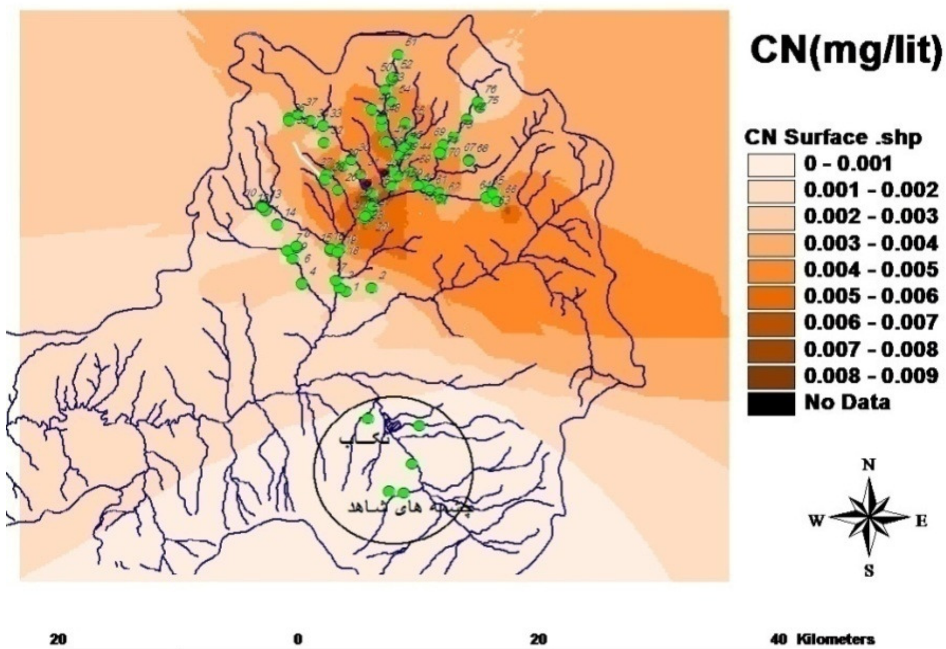
Figures 5: Results water temperature (C°) in the samples studied springs using Arc GIS



Figures 6: Results concentration of total dissolved solids (mgl^{-1}) in the samples studied springs using Arc GIS



Figures 7: Results salinity (percentage) in the samples studied springs using Arc GIS



Figures 8: Concentration cyanide check in springs compared with gold extraction plant

from Figure 8, Cyanide concentrations for all springs are located in the mean range of springs Cyanide (0.004 mgl^{-1}). Cyanide concentrations in the control springs have been zero or nearly zero.

DISCUSSION

In this study was an examined water spring in Gold extraction plant village's area (From a distance of 12 km)

In order to affect a spring water of Cyanide in Takab. Based on the results obtained in this study, the highest concentration of cyanide has been 0.009 mgl^{-1}that is lower amount reported by the World Health Organization (0.07 mgl^{-1}) as a safe level to prevent acute toxicity. So we can say there will not be Specific health effects Due to the water springs consumption. According to the results in Table 3, there has been a significant relationship between concentrations of cyanide in water springs with spaces from gold extraction plants ($P< 0.0001$). In a study that was conducted by the Taebi and his colleagues (Taebi et al., 2006), had decreased than the amount of cyanide with distance from the tailings dams (sources of pollution). The researchers concluded that cyanide concentrations in soils with spaces from the pollution source Represents the releases cyanide from tailings ponds into the environment that is consistent with Results of this study. In a study by Li Shehong and his colleagues (Shehong et al., 2005), that performed In connection with the evaluation of the natural decomposition of cyanide in a river in north-western China, Concluded that degradation rate of cyanide in open environments in static state in laboratory conditions More than dynamic state in a closed environment.

This should be noticed that the mean concentration of cyanide in the environment has a decreasing trend with time. Therefore, if the sampling time of the springs and therefore time of release cyanide gold extraction plant operating environment is not appropriate, were reported concentrations of cyanide Cannot be represent the actual concentration of cyanide be entering the environment. In a study was conducted by Taebi and colleagues (Taebi et al., 2006), Results shown that rate of cyanide decrease in early days of the environment more than it long term rate.

The main causes can be decrease residual cyanide concentration gradient in the soil environment. In other words, according Fick's laws of diffusion, with decreasing gradient concentration cyanide in soil, cyanide transfer Rate reduced from soil to water springs. Also in several studies reported which in case period tillage operations on soil Due to the increase in soil pores, increases Contact the lower layers with the atmospHere. So resulting would be Escape cyanide as hydrogen cyanide gas into atmospHere (Rahmani et al., 2013). Furthermore, due to rummage soil and aeration operation consequently, Biological degradation of cyanide can be increased by aerobic bacteria. AtmospHeric conditions and the rate precipitation and air temperature are important parameters on stability of cyanide in the environment (Donato et al., 2007). In the present study, due to budget limitations there wasn't the possibility reviews cyanide concentration during different times of the year that to be realized the relationship between different levels of cyanide concentrations in water springs in Different periods of time in a year. But based on the results of similar studies, can be said that in warm seasons (Sampling time in this study), due to more and more serious radiation solar radiation, increased possible destruction of cyanide in the environment and thus is reduced this concentration in the environment. As well as in Rainfall season Due to cyanide washing the soil and transfer it to the soil the lower layers and thus water sources, there is a More Possibility cyanide concentration in water samples from springs. This subject should be investigated in more comprehensive studies.

According to were measured physicochemical properties of water springs, PH changes at different distances from springs the gold extraction plant not has been a clear trend of to increase or decrease. Also Statistical analysis had not shown relationship between the pH of spring water and distance of the gold extraction plant ($P= 0.63$). The mean pH in spring's samples had been 7.38± 0.368. Also there are significant differences between pH in water samples main and control springs ($P= 0.0008$). In the gold extraction plant during process of extracting gold, are added of lime to water to increase pH. This work can be done for prevent the cyanide escape into gas in acidic pH.

This should be noticed that Depending on the type geological characteristics of the area May be due to precipitation and thus leaking of rain water, than can be seen pH change (as increase or decrease) in rain water samples. Also In the studied region are visible the Freshwater limestone in white and Yellowish -white, which thickness It reaches in some areas to over 500 meters that starting in Takht-e Soleymān and had passed from Ahmdabad. Travertine stones there are around the Agh-Darreh, Ghinerje and Yangikand village. As well as during the time is reduced the pH due to the water leaking of rain water and also increase the absorption of carbon dioxide (Neutralize alkalinity water springs). According to the results, the mean electrical conductivity has been 656.3±397.45 μscm^{-1} in studied springs ($P= 0.005$). Nevertheless, was not observed the significant difference between electrical conductivity in main and control springs ($P= 0.24$).

According to the results presented in Table 3, there is a significant relationship between pH and EC in studied springs. Increases the electrical conductivity same time decreasing pH could be due to dissolved metals during low pH as metal salts solution($NaCl$ ،$MgSo_4$ and $CaSo_4$), that Lead to Increase the electrical conductivity of water. Since has Make up large part of area travertine stone (are Component carbonate stones and have been formed of limestone and dolomite Cretaceous period) springs in the area had been come to dissolution of this stones. Thus, Water springs have high elements and will be increased salinity levels in the water.

Geographic Information System (GIS) is information systems which will assessment the production, processing, analysis and management of geographic information (Spatial Information). In other words, GIS is a computer system for the management and analysis of

Spatial Information Which have capability collected, store, analyze and display geographic information. The ultimate objective of a GIS, is supported for decisions Established on spatial data. It basic the performance is obtaining information that is achieved from combining different layers of data with different methods and different perspectives. In this study, to express the results of pHysicochemical analysis as well as measurement of cyanide, was used The GIS.

CONCLUSIONS

In this study can be conclusions the following: 1) amount of cyanide in water springs has been a significant inverse relationship with Distance from gold extraction plant so whatever springs have nearer to the gold extraction plant, the more cyanide have been identified in water samples. 2) Significant difference there has been between pHysicochemical parameters (pH, EC, Sal. Water temperature and total dissolved solids) in the studied springs But Significant difference were not observed for cyanide. 3) From quantities had obtained the measured parameters for the main and control springs, significant difference only was observed for pH. Use of the geographical information system is very useful for the expression of results and could be showed the results achieved as illustrative and comprehensive.

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