Salt contamination of Apulian aquifers: spatial and time trend

M. Polemio, V. Dragone and P.P. Limoni

Abstract The quality of groundwater of Apulian carbonate aquifers is severely affected by salt contamination due to seawater intrusion. Due the scarcity of surface water resources, the characterization of groundwater quality degradation risks and of spatial and temporal trend of degradation are particularly important in the region.

To pursue these results considering the risk of salt contamination due to seawater intrusion, a simple salinity threshold approach, based on the determination of a single value dividing fresh groundwater from seawater contaminated groundwater, is proposed for Apulian groundwater. The threshold can be considered equal to 0.5 g/l for the Apulian karstic and costal aquifers. The spatial trend of 0.5 g/l salinity contour line in the period 1981 2003 is characterized. Along the areas close to the Adriatic and Ionian shoreline groundwater saline contamination is resulted to be a long standing phenomenon. Only the Murgia interior and a restricted strip in the middle of the Salentine Peninsula have not been contaminated so far.

The salt contamination is also characterized considering 17 time series of monthly chloride concentration, a parameter which can highlight the seawater contamination effects. Data from 1968 to 2001 are considered and compared with rainfall and temperature time series. The increased saline contamination is closely related to droughty years and to the increasing discharge by wells. Before 1980, no significant concentration increase was reported in the majority of wells. The phenomenon became apparent in the late 80s after some dry years that result in a reduced recharge of aquifers and increased groundwater withdrawals. Time series of mean annual values of specific electrical conductivity are also discussed.

It is confirmed the existence of areas considerable protected from the seawater intrusion, of areas exhibited in serious manner to the salt pollution and, finally, of an immense portion of territory in which the quality of the groundwater depends exclusively from our capacity to manage the water resources.

Index Terms groundwater, pollution, seawater intrusion, Apulia.

I. INTRODUCTION

The Apulian coastline is 800 km long; the region is the site of the largest coastal karstic aquifers in Italy, country in which the main cause of saline pollution is the seawater intrusion. Studies lasting decades, carried out with the most advanced technologies, realizing geological, hydrogeological and geochemical surveys have clearly shown that the degradation risks and the extent of seawater intrusion is higher in the Apulia Region (Cotecchia et al. 2005).

The Apulian territory is prevalently of karstic nature. For the selected study area, the Murgia plateau (hereinafter Murgia) and the Salentine lowlands (Salento), the groundwater discharge is greater than double the surface runoff (Polemio & Limoni, 2006). For this reason the availability of surface water resources is very low while the groundwater resources are the main regional source of water which still contributes to social and economical development of local population.

The specific nature of groundwater resources of coastal and karstic aquifers, in terms of recharge, flow and discharge processes, the high intrinsic vulnerability of the aquifers to the anthropogenic pollution and the effects of seawater intrusion due to high well discharges make complex and relevant the wise management process and the correct use.

The characterization of risks of quantity and quality groundwater degradation is a subject of current and relevant importance on which the scientific contribution can be decisive to highlight underestimated risks of seawater pollution effects and of anthropogenic pollution (Polemio, 2000). Monitoring seawater intrusion is essential in order to determine and predict groundwater degradation, and in order to define management activities for coastal aquifers. The main goals are the identification of quantitative and quality trends and the degradation of availability due to salt pollution and the risks for groundwater resources, using a number of methodologies. These tools should be simple, quick affordable and as cheap as possible.The article describes the application of some tools defined to show the spatial and temporal trend of quality degradation due to the effects of salt pollution for seawater intrusion, considering the selected study area.

II. GEOLOGICAL AND HYDROGEOLOGICAL SETTING OF TEST AREA

Murgia and Salento are constituted of limestone of the Apulian shelf; the Gargano is constituted mainly of reef rocks (Fig. 1). The Apulian shelf emerged at the end of the Cretaceous and became part of the foreland of the south-Apennines chain (and was divided into three structural domains, the Gargano, Murge and Salento structural highs) (Beneduce et al., 2004).

Manuscript received September 2006

Authors are with the National Research Council, CNR-IRPI, via Amendola 122/i, 70126 Bari, Italy (the corresponding author is M. Polemio, phone: +39 080 5929584; fax +39 080 5929610; e-mail: m.polemio@ba.irpi.cnr.it).

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The subsidence starting from the middle Pliocene transformed these highlands into islands. Transgression led to the deposition of tertiary-quaternary soils and rocks that separated the Gargano from the outcropping Apulian shelf, where the shelf was either lowered thousands of meters (Tavoliere area) or covered the karst of the Murgia and of the Salento with thin strata of sand, conglomerates, calcarenites, limestones and clays. From the middle Pleistocene on, the whole region began to uplift; in the Holocene, the Salento and the southern part of the Murgia were affected by a slow uplift of 0.08 mm/yr (Grassi, 1983; Beneduce et al., 2004; Lambeck et al., 2004; Cotecchia et al. 2005).

The Murgia and Salento Mesozoic rocks form a lithological, geological and groundwater continuum (Grassi, 1983). The hydrogeological structures are bounded by the coastline and by the Pliocene or more recent faults. The boundary, between the Tavoliere and the latter and the Murgia is clear cut. On the contrary, the boundary between the Murgia and the Salento is uncertain; they are separated by a morphological-structural element called the "Soglia Messapica" which covers an area extending from Adriatic to Ionian Sea, about 10 km wide. In this area a gradual shift of hydrogeological features can be observed from Murgia to Salento as the depth to groundwater (respectively from high to low and from middle to low) or the hydraulic conductivity (from middle to low, mildly variable and from high to middle).

The Murgia and Salento aquifer is made up of Mesozoic rocks of Apulian foreland (Fig. 1). The aquifer is affected by karstic and fracturing phenomena well below the current sea level, whereas intruded seawater underlies fresh groundwater owing to a difference in density.

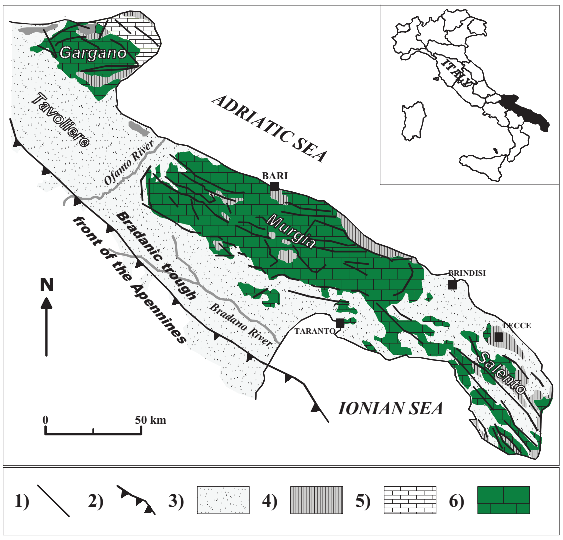

Fig. 1. Geological scheme (modified after Beneduce et al., 2004). 1)Fault, 2) front of the Apennines, 3) recent clastic cover (Pliocene Pleistocene), 4) bioclastic carbonate rocks (Paleogene) and calcarenites (Miocene), 5) carbonate platform rocks (Upper Jurassic-Cretaceous), 6) scarp and basin chert-carbonate rocks (Upper Jurassic-Cretaceous).

Confined groundwater flow is almost widespread inland only in the case of Murgia; groundwater is phreatic everywhere along a narrow coastline strip which surrounds the region.

III. The spatial variability of salinity

The multitemporal spatial analysis of salinity is a method based on the determination of a threshold salinity value between pure fresh groundwater and groundwater contaminated by seawater.

The threshold must be determined for the local hydrogeological conditions, considering the specific chemical-physical characteristics of rainfall, the geochemical nature of rocks and local factors that define the variability of fresh groundwater salinity.

This approach can utilize historical data, determined by monitoring boreholes and by pumping wells which are also owned by private parties. In this case, it is possible to reach high or the highest spatial density of measurements that is locally possible.

The threshold is about equal to 0.5 g/l for Apulian karstic and coastal aquifers (Polemio and Limoni, 2001) This limit or threshold is almost a upper limit for high quality groundwater; it is about not exceeded if the salt pollution for seawater intrusion of pure fresh groundwater is not happened, as shown considering a data set constituted by about 500 analyzed groundwater samples (Cotecchia & Polemio, 1999) (Fig. 2). The selected threshold value is coherent with studies of chemical nature of recharge water considering the effects of rainfall and of dry depositions (Cotecchia et al., 1973) and is equal to the value suggested by Cotecchia et al. (1983).

The spatial evolution over the time is determined considering TCL of 1981, 1989, 1997 and 2003. The 1981 and 1989 data were collected during surveying carried out within the framework of two regional plans for the management of water resources and of water use; respectively, the water protection plan (Regione Puglia, 1984) and the aqueduct general plan (LL.PP., 1989). The salinity data of Apulian groundwater, referred to 1997, were measured in wells of the Apulian groundwater monitoring system (Colucci et al., 1998; Cotecchia & Polemio, 1999). At the end, the data referred to 2003 has collected by IRPI that has carried out a survey in the above mentioned wells (Fig. 2).

Using data measured by hundreds of wells, the TCLs have been determined using geostatistical methods; their spatial modifications can be highlighted by GIS applications. The low density of monitoring wells and the high percentage of gaps do not permit the detailed characterization of spatial and time variability of salinity in the case of Gargano, which is not considered in detailsTo assess the spatial and time trend of salt contamination due to seawater intrusion for Apulian groundwater, the analysis considers the trend of 0.5 g/l salinity contour line in the period 1981-2003 (Fig. 3); three types of areas are distinguishable

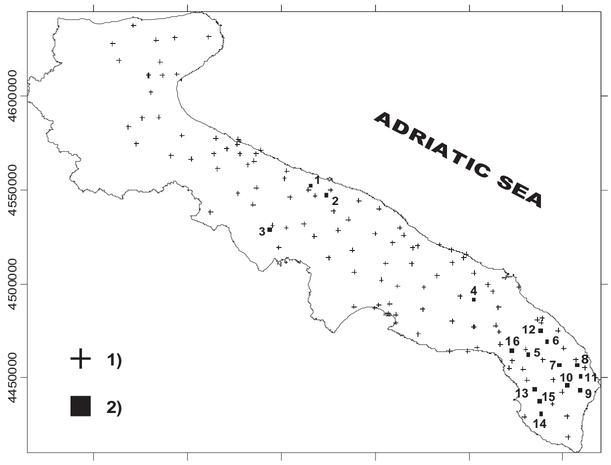

Fig. 2. Location map of monitoring points; 1) sampling wells and springs, 2) chloride time series wells.

The first type is located where the salinity is permanently below the threshold. It is an inland type: a wide portion of inland Murgia and a restricted strip in the middle of the Salentine peninsula have not been contaminated so far; it can be considered at low vulnerability to the degradation risk for salt pollution.

The second type is linked to the areas where salinity is always greater than threshold and the groundwater saline contamination resulted to be a long-standing phenomenon. This type can be distinguished in large areas along the Adriatic and Ionian shoreline in which the vulnerability to salt pollution is very high. The third type is an intermediate or transitory type: in each point of these areas the salinity is a function very sensible of anthropogenic and natural modifications of water cycle and, mainly, of human capacity to manage groundwater resources considering the water cycle variations. It is interesting to note the salt contamination of fresh groundwater due to seawater intrusion, highlighted by salinity values always greater than threshold, is an almost irreversible qualitative characteristic or a high probable steady qualitative status in a wide strip located along th Adriatic and Ionian coast. In other words, a continuous coastal strip of variable width shows salinity greater than 0.5 g/l from 1981 to 2003. This type of area shows a very high vulnerability to salt pollution for seawater intrusion.It is on the contrary distinguishable an inland type of area or zone where the salinity is permanently below the threshold quite apart from the observed climatic variability relevant for the recharge (Polemio & Casarano 2004) and the modification of well discharges. It is a wide portion of inland Murgia and a restricted strip in the center of the Salentine peninsula. They have not been contaminated so far; the type of area can be considered at low vulnerability to the risk of degradation due to salt pollution for seawater intrusion. Between these two type of areas a third type, an intermediate or transitory type or zone, can be distinguished: it is a wide portion of territory interested by the fluctuation of the reference contour line 0.5 g/l, which showed relevant movements upward or downward from 1981 to 2003. The vulnerability to salt pollution for seawater intrusion can be variable in this intermediate zone but it is nowhere low; the sustainable management of the coastal aquifer requires here discharge by wells should be optimized avoiding upconing and the inland and lateral migration or intrusion of saline groundwater.

The relevant and current salt contamination of fresh groundwater can be also assessed considering the map of specific electrical conductivity (SEC hereinafter) of Salento groundwater, obtained on the basis of 2000 annual mean obtained by sampling of groundwater discharged for drinking use by the water company. Defining three classes or ranges, the groundwater of the best quality or very fresh, SEC<750μS/cm at 25 C°, is recognizable in restricted areas located inland (Fig. 4); this class seems almost an exception if the spatial extension is compared to the whole Salento area. Fresh groundwater of sufficiently good quality are discharged in the whole area in which 750μS/cm<SEC<1500μS/cm at 25 C°. SEC increases moving downward or from inland to the coast: SEC is greater than 1500μS/cm at 25 C° in more than 50% of the whole Salento territory. This class can be distinguished in a wide and continuous strip located along the Adriatic and Ionian coast.

The 2000 SEC map confirms there is wide portion of Salento in which the salinity is variable due to the effect of salt pollution for seawater intrusion but also it confirms that should be possible narrowing the contamination in a costal strip as narrow as the management processes of fresh groundwater are effective (Fig. 4).

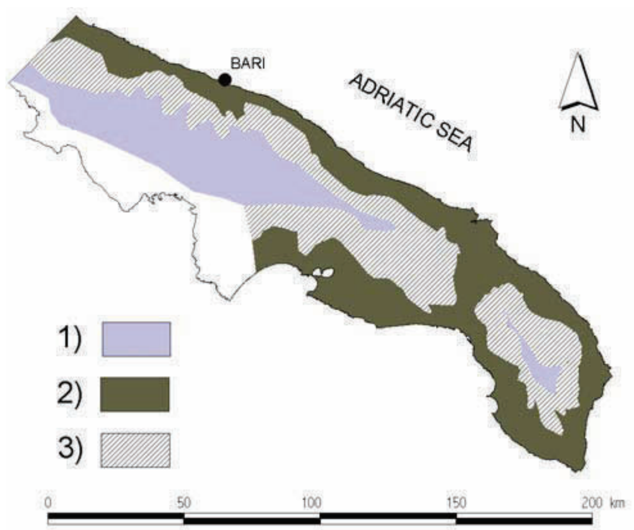

Fig. 3. Map of areas with degraded groundwater and vulnerable to salt pollution for seawater intrusion effects: 1) salinity always less than 0.5 g/l, low vulnerability to salt pollution; 2) salinity always greater than 0.5 g/l, very high vulnerability to salt pollution; 3) salinity less or greater threshold as function of time, from mean to high vulnerability to salt pollution.

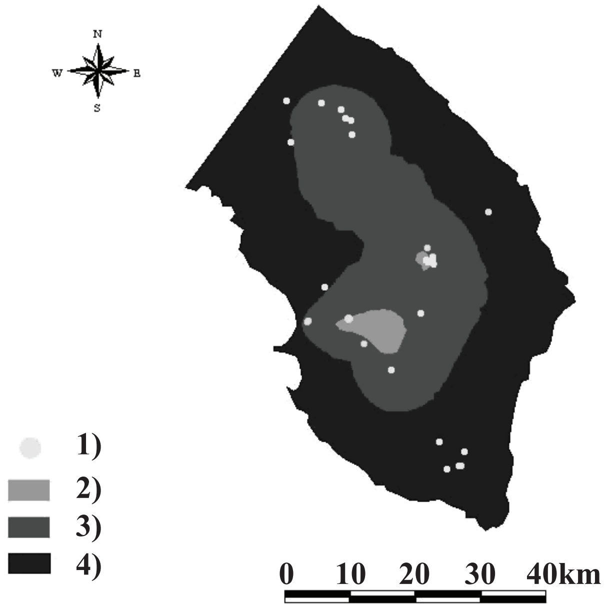

Fig. 4. Map of 2000 mean specific electrical conductivity (SEC) of Salento; 1) well, 2) SEC<750 µS/cm at 25C , 3) 750<SEC<1500 µS/cm at 25C 4) SEC>1500 µS/cm at 25C .

IV. The salinity trend analysis

The salinity trend analysis requires regular and long-lasting measurements. In the absence of time series acquired due to the activity of a quality groundwater monitoring network, the tool considers that a very high linear correlation should exist between the concentration of some ions and the salinity of groundwater, particularly if affected by seawater intrusion or by other sources of salt pollution. At same time, it is useful to consider that the concentration of some ions is traditionally determined by private parties for many reasons and in many countries it is obligatory to determine the concentration of ions, somewhere on a daily basis, and has been for decades, if groundwater is supplied for drinking purposes.

The chloride ion concentration (CC hereinafter) can be a good choice to evaluate the salinity of Apulian karstic and coastal groundwater, as shown by a data set constituted by 500 analyzed groundwater samples, for which the linear correlation coefficient is equal to 0.98 (Polemio & Limoni, 2001). The chloride ion is an almost particular ion as its concentration variation, more than the remaining main ions, is mainly due to mixing with another water body, seawater, and not to processes of rock/water interaction.

Analyzing the data set, the most probable chloride ion concentration in groundwater with salinity equal to 0.5 g/l is 60 mg/l and for CC>100 mg/l is always superior to 0.5 g/l. Groundwater samples that can be free from salt pollution due to seawater mixing show about CC less than 50 mg/l.

16 reliable time series of quite continuous monthly data has been selected (Fig. 2). The chloride concentration is measured by wells pumping drinking water.

The linear trend is expressed by the angular coefficient AC of the linear trend (Table 1). It is worthy of note that the latest data are antecedent to the latest drought period, 1999-2002, in the case of the Murgia (1998) and are only partially contemporaneous with the beginning of the drought in the case of the Salento (2000-2001).

The trend or AC is generally negative for Murgia wells (1, 2, and 3), with a drop in chloride concentration. The trend of well 4 would appear to be an exception, but this very low positive trend is not statistically significant at 5%; it is the well with the minimum value of mean annual concentration. These results summarize the Murgia situation at 1998, after a favorable period of two rainy years (Polemio and Casarano, 2004).

The time series variability can be considered as overlapping of different components. The analysis of the seasonal component is based on the time series decomposition in order to provide information about the seasonal salinity regime. Regarding the Murgia wells, it is possible to observe that the CC regime shows an increasing trend during the summer, arid season during which the natural decrease of the piezometric level is emphasized by irrigation discharge. The increasing CC trend lasts up to September or October. CC generally decreases down to the minimum during or after the rainy months, generally from October to January or March. The regime range is generally less than 6% of the mean concentration.

The appreciable cyclic nature of the seasonal CC regime of Murgia seems to be almost statistically related to the rainfall regime, which shows only a peak during autumn-winter and a minimum in summer, to atmospheric temperature regime, which shows only a minimum during winter and a summer, and to net rainfall regime, equal to zero from the end of spring until the autumn begging.

The CC annual trend is quite different and more serious in the case of the Salento at the end of 2000, where the trend is mainly positive and AC ranges from 0.06 to 5.72 mg/(L yr). The only exception is of wells 12 and 16; these wells are located, as the Murgia well 4, in the Soglia Messapica zone, where a main groundwater flow path goes from the recharge area of the Murgia guarantees to the Salentine portion of the aquifer. A point to bear in mind is that, when the salinity increases too much in a vulnerable zone to permit the water use, the wells are abandoned in that zone, causing a local discharge decrease and then a local improvement of quality. This figure complicates the discussion of salinity trend, especially where the salinity is quite high, as in the case of wells 12 and 16, for which the maximum annual concentration of chloride is observed.

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TABLE 1 ANNUAL CHLORIDE STATISTIC (MG/L). HS) HYDROGEOLOGICAL STRUCTURE M) MURGIA AND S) SALENTO; BY) BEGGING YEAR AND FY) FINAL YEAR OF DATA AVAILABILITY; AC) ANGULAR COEFFICIENT OF LINEAR TREND (G L-1 YR-1).

Well	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
HS	M	M	M	M	S	S	S	S	S	S	S	S	S	S	S	S
Min	25.7	28.2	18.9	25.5	85.2	237.4	80.5	38.1	56.1	31.1	74.5	134.8	201.4	170.4	138.5	266.3
Average	35.6	63	33.6	32.3	106.1	314.9	146.6	58.9	90.9	40	91.1	189.1	227.4	204.9	193.7	354.1
Max	40.4	80.9	57.8	51.1	141.3	378.4	238.2	258.5	147.1	65.7	104.9	236.1	261.3	244.9	273.4	390.5
BY	1973	1973	1968	1975	1973	1969	1973	1980	1973	1981	1971	1973	1968	1969	1975	1973
FY	1998	1998	1998	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2001	2000
AC	-0.076	-0.164	-0.557	0.007	1.532	2.187	5.719	3.16	2.56	0.084	0.058	-0.478	0.773	2.042	1.063	-0.759

TABLE 2 STATISTIC OF ANNUAL SPECIFIC ELECTRICAL CONDUCTIVITY (μS/CM AT 25 C). HS) HYDROGEOLOGICAL STRUCTURE M) MURGIA AND S) SALENTO; BY) BEGGING YEAR AND FY) FINAL YEAR OF DATA AVAILABILITY; ACC) ANGULAR COEFFICIENT OF LINEAR TREND (μS/(YR CM) AT 25 C).

Well	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
HS	M	M	M	M	S	S	S	S	S	S	S	S	S	S	S	S
Min	789.2	599.5	566.0	702.8	824.3	1282.6	635.8	623.2	615.3	629.2	611.1	1039.5	1089.3	944.5	979.0	1413.5
Average	850.0	900.0	612.6	773.6	974.3	1553.3	879.3	658.2	754.9	770.4	629.6	1254.2	1273.1	1163.3	1254.1	1859.5
Max	930.1	1022.0	665.5	867.1	1079.1	1759.2	1139.1	708.7	943.3	891.0	661.1	1441.5	1514.4	1423.8	1492.7	2337.5
BY	1975	1973	1971	1975	1974	1973	1973	1984	1973	1971	1984	1973	1973	1973	1975	1973
FY	1990	1990	1991	1990	2000	1991	1991	1991	1991	1991	1991	1991	1991	1991	2000	1991
ACC	0.07	6.76	1.25	1.35	9.28	25.46	25.79	0.06	15.52	6.08	5.54	21.28	21.74	18.92	17.62	17.35

Trend analysis confirms the result of spatial TCL analysis, offering greater definition in the time domain. The increasing saline contamination of the Salento groundwater is confirmed.

An analysis of the data shows that the increased groundwater saline contamination is closely related to overexploitation and to rainy-drought periods. Before 1980, no significant concentration increase is reported in the majority of wells. The phenomenon became apparent in the late 80s after some dry years that resulted in a reduced recharge of aquifers and in increased groundwater discharge for agricultural purposes (Polemio & Casarano, 2004).

The observed CC regime of Salento wells is less regular and homogenous; the seasonal nature of CC seasonal component is practically not recognizable; the seasonal variability does not seem due to natural processes but it seems the overlapping effect of widespread discharge by wells.The salinity can be also estimated on the basis of the specific electrical conductivity of groundwater, determined at a reference temperature. SEC time series have been selected for some discharging wells; data are available from 1971 to 2000 (Table 2). The trend analysis can be summarised considering the angular coefficient of specific electrical conductivity ACC; ACC ranges from 0.06 to 25.79 μS/(yr cm) at 25 C° in Salento and from 0.07 to 6.76 μS/(yr cm) at 25 C° in Murgia. The correlation between statistic values is very high if mean annual CC and SEC values are considered and it is low if the trend values (AC and ACC) are considered; the former figure can be justified considering the SEC time series are generally shorter, with final year generally equal to 1991 and not to 1998 (Murgia) or 2000 (Salento) as in the case of CC time series. The trend quality due to salinity is worst in the case of SEC analysis, particularly in Murgia, as the effect of a huge drought hit the region in 1989-1990 (while 1996-1997 was a quite rainy period) (Polemio & Casarano 2004).

The increasing trend of salinity is widespread observed and confirmed by the specific electrical conductivity trend analysis.The value at a time of a hydrological or hydrogeological parameter X constituting a time series can be dependent from values of X which have been observed before. In this case, it could be possible to determine a characteristic of the variable which can be called persistence or memory effect, which is a measure of the time series capacity to show values which are correlated to previous values. The persistence is assessed using the autocorrelation analysis, based on the determination of the linear correlation coefficient between X_t and X_{t-k}, with t and k positive and integer numbers, where t is the position in the time series and k is the lag. The autocorrelation analysis is based on correlation analysis between time series X_t and K time series

X_{t-k}; for each value of lag the autocorrelation coefficient is determined. The maximum absolute value of correlation coefficient (V), the month lag in which V is observed (M) and the maximum month lag of statistically significant correlation (L) can be considered attributes of the persistency.If the correlation analysis is based on the use of two different parameters and time series, X and Y, the linear correlation coefficient is called crosscorrelation coefficient, it is determined between the variables X_t and Y_{t-k}.

The autocorrelation analysis and the crosscorrelation analysis have been applied to some selected monthly CC time series. Some hydrogeologically appropriate temperature and rainfall monthly time series have been selected for the crosscorrelation analysis.

All CC series show a short but significant memory effect (Table 3): generally the max autocorrelation coefficient (V) is caught up with month lag (M) equal to 1. The current CC value or the CC value of this month heavily determines the value will be detected next month. This effect quickly runs off, generally within a month. The max coefficient V is generally about equal to 0.4. The only exception regards the well 13 in which the max autocorrelation coefficient is 0.81.

TABLE 3 RESULTS OF MONTHLY CORRELATION ANALYSES. HS) HYDROGEOLOGICAL STRUCTURE M) MURGIA AND S) SALENTO; M) MONTH LAG OF MAXIMUM CORRELATION COEFFICIENT; V) MAXIMUM CORRELATION COEFFICIENT; L) MAXIMUM MONTH LAG OF SIGNIFICANT CORRELATION; NC) NOT CORRELATED

Well		**2**	**3**	**9**	**10**	**13**	**15**	**16**
HS		**M**	**M**	**S**	**S**	**S**	**S**	**S**
Auto correlation	*M*	1	1	1		1	1	1
	V	0.35	0.39	0.35		0.81	0.37	0.4
	L	3	4	2		3	1	2
Cross correlation with rainfall	*M*	1		3	3	4	4	nc
	V	0.20		0.23	0.31	0.25	0.21	nc
	L	1		4	3	5	5	nc
Cross correlation with temperature	*M*	1		2	2	3	2	1
	V	0.16		0.39	0.17	0.15	0.18	0.31
	L	2		4	3	3	3	2

The crosscorrelation between CC and rainfall is generally negative. The crosscorrelation seems higher in Salento, where the maximum absolute value of the crosscorrelation coefficient ranges from 0.21 to 0.31, than in Murgia, where the absolute value of the crosscorrelation is equal to 0.20. This circumstance could be due to the higher CC contrast between groundwater and rainfall in the case of Salento. The maximum significant month lag L is equal to 3-4 months in Salento and 1 in Murgia and it is equal to M or a month greater than M in both hydrogeological structures. A Salento CC time series the crosscorrelation with rainfall is not statistically significant.The crosscorrelation between CC and temperature is everywhere positive: while the temperature increases, the rain stops and groundwater discharge consequently increases. Such process can cause salt pollution for seawater intrusion, justifying the CC increase. The crosscorrelation seems again higher in Salento, where the maximum crosscorrelation coefficient ranges from 0.15 to 0.39, than in Murgia, where the absolute value of the crosscorrelation is equal to 0.16. The maximum significant month lag L is equal to 2-3 months in Salento and 2 in Murgia and it is equal to M or a month greater than M in both hydrogeological structures. The CC-temperature crosscorrelation seems somewhere more significant than CC-rainfall and it is nowhere without statistical significance.

V. CONCLUSION

Groundwater flow is not only the main hydrologic factor in the dynamics of the karst, but also determines the development of human communities and the ecological equilibrium of coastal wetlands and of surface water bodies in the case of karstic coastal aquifers. In these cases, monitoring is essential to determine and predict groundwater degradation, and to define management activities for coastal aquifers.Applying spatial trends of TCL to Apulian aquifers highlights three types of areas: areas with low/ vulnerability to seawater intrusion in which the salinity is always less than threshold, areas with high vulnerability to seawater intrusion in which the salinity is always greater than threshold and areas with variable but not low vulnerability in which the salt degradation depend mainly from the capacity to manage the discharge.

A time series analysis of monthly chloride concentrations shows that increased saline contamination is closely related to droughty years and to the increasing discharge by wells for Apulian aquifers. The phenomenon became valuable in the late 80s after some dry years that resulted in a reduced recharge of aquifers and in increased groundwater discharge. Any description of quality degradation risk of Apulian groundwater resources due to seawater intrusion confirms the existence of areas considerably protected from seawater intrusion, of areas seriously exposed to salt pollution and, finally, of an immense portion of territory in which the quality of the groundwater depends exclusively on capacity to manage water resources.

The remarkable spatial and temporal variability of the salinity and the widespread salinity increase of Salento groundwater show that quality degradation risks of groundwater resource are serious. The preeminent cause of salinity worsening is the absence of a correct planning and management of groundwater resources uses, now subjected to a diffuse overexploitation.

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