Indicators and quality classification applied to groundwater management in coastal aquifers: case studies of Mar del Plata (Argentina) and Apulia (Italy)

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Abstract The use of indicators is considered for environmental and ecological monitoring and in the general assessment of environmental sustainability at a local, national and international scale. They are used to briefly describe the interests and preoccupations of society with regard to environmental evolution, and to coherently aid in decision-making processes. Groundwater is affected by two types of degradation risks: quality and quantity degradation. In order to define the coastal environmental processes related to groundwater resources, some indicators addressed to decision makers and quality classification are proposed and discussed in relation to two different types of coastal aquifers located in different countries: the porous aquifer of Mar del Plata (Argentina) and the Salentine karstic aquifer (Italy). Beyond the strong hydrogeological differences between both areas, the analysis of indicators allows the identification of interesting similarities. The results show this approach could help in reaching a consensus to propose a methodology to deal with environmental quality assessment of water and establish groundwater exploitation criteria.

Key words coastal aquifer; management; monitoring; environmental sustainability; groundwater; indicators; degradation risk; seawater intrusion; pollution

INTRODUCTION

Two coastal aquifers are considered in two very different geographical, hydrogeological and socio-economic territories, the first being located in Argentina and the second in Italy. The use of indicators and quality classification criteria of groundwater are applied to test their usefulness in contributing to the sustainable management and reduction of degradation risk of coastal groundwater resources

The main and common environmental problems related to water resources are: high urban area expansion, seawater intrusion, pollution of groundwater, inadequate waste management, and recurrent or rare flash floods in urban and surrounding areas.

Mar del Plata, located on the Atlantic coast, is the main tourist centre in Argentina, and has a population of 600 000 inhabitants that increases threefold during the summer. Water for urban, agricultural and industrial uses is supplied solely by groundwater resources.

Due to a law on building (blocks of flats), especially since 1948, the urban growing process has led to an increase in population density, industrial activities (building, food, textile and fishing) and tourism in the central area.

Several studies have been carried out characterizing the process of seawater intrusion (Bocanegra *et al.*, 1993, 2002; Martínez *et al.*, 1996) and the impact of leachates at final waste disposal sites on groundwater (Massone *et al.*, 1993, 1994, 1998; Bocanegra *et al.*, 2001a ; Mascioli *et al.*, 2005).

The Apulia region is located in the southeastern portion of Italy. The whole Apulian groundwater has undergone a two-fold pollution, both originated by human action (Polemio, 2000, Polemio & Limoni, 2001): salinization has evolved progressively as it has affected increasingly larger portions of land; and biological and chemical-physical pollution has gained importance and is mainly concentrated around urbanized areas (Cotecchia, 1981; Cotecchia & Polemio. 1997).

Carbonate rock outcrops are widespread in three areas of the region; in these areas the natural protection of the aquifer by pollution is very low. The intrinsic vulnerability of main aquifers, which is spatially variable but significant everywhere, exposes groundwater almost directly to effects of potential pollution sources from anthropogenic activities at the land surface. The natural or intrinsic vulnerability is increased by using custom-bored wells, karstic pits and dolines to discharge underground wastewaters and runoff from urbanized surfaces.

HYDROGEOLOGICAL FEATURES OF MAR DEL PLATA AND SALENTO AQUIFER

Mar del Plata is located on the northeastern side of the Tandilia range, and it is the most important sea-side resort of Argentina (Fig. 1). The Tandilia range has a maximum altitude of about 40 m a.s.l. in the Mar del Plata area. In the study area, the range consists of lower Palaeozoic quartzites, grouped under the name of Balcarce Formation (Dalla Salda & Iñiguez, 1978). The quartzite bedrock is overlain by a sedimentary cover of Upper Tertiary and Quaternary silts and silty-to-sandy sediments. Miocene clayey-to-sandy sediments are found at a depth of 60 m in the grabens. The Quaternary deposits are called "pampean sediments" or "loess-like sediments" and, from a hydrogeological viewpoint, they constitute the most important sequence. They are a multi-layered phreatic aquifer with a thickness ranging from 70 to 100 m, and a hydraulic conductivity is 10 m/d. The transmissivity is about 600–800 m^2/d in the urban area and between 1000 and 1400 m^2/d in the rural area. The storage coefficient, estimated from pumping tests, is 0.001, and the porosity is 0.15.

The Apulia region is characterized mainly by the hydrogeological units of the Gargano and Tavoliere and the hydrogeological structures of the Murgia and the Salento. All of these areas are carbonate in nature, except for the Tavoliere, and constitute the largest coastal karstic aquifers of Italy, made up of Mesozoic rocks (Fig. 2). A detrital organogenic series (Tertiary and Quaternary) fills some troughs or partially overlaps the carbonate rocks, creating secondary aquifers in places (Cotecchia *et al.*, 2004).

The study area corresponds to a morphological-structural unit—the Salento—a lowland area (maximum height about 180 m a.s.l.), bounded by the Adriatic Sea and the Ionian Sea. The Mesozoic carbonate rocks are more widespread and covered by outcropping Quaternary soils and rocks where these outcrops are not very continuous (Fig. 1). The Salento peninsula (Fig. 2) corresponds roughly with the province of

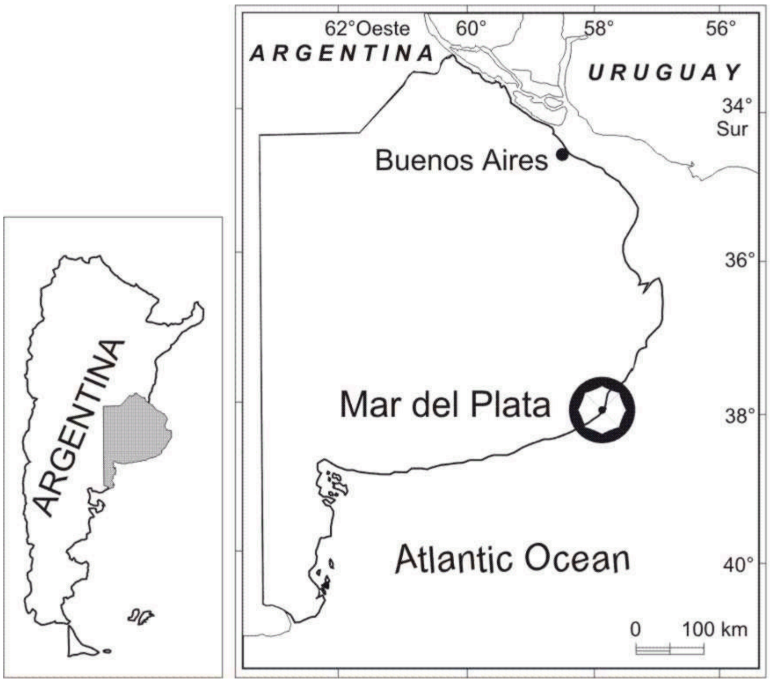

Fig. 1 Mar del Plata location map.

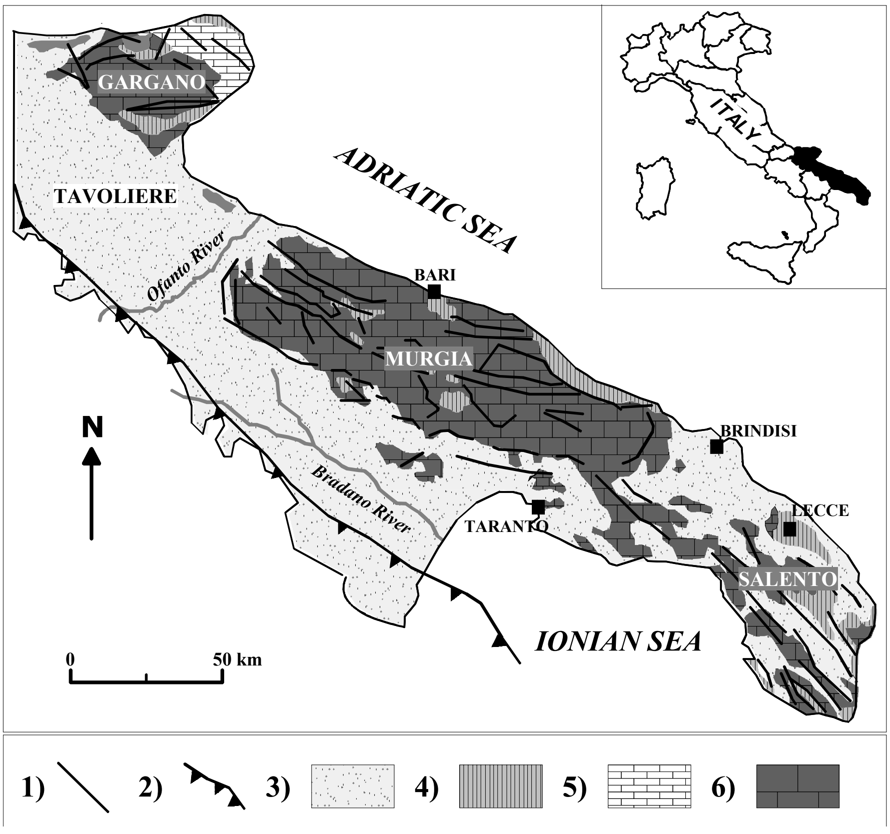

Fig. 2 Salento location map and geological scheme of Apulian hydrogeological units and structures. 1: Fault; 2: front of the Apennines; 3: recent clastic cover (Pliocene–Pleistocene); 4: Bioclastic carbonate rocks (Paleogene) and calcarenites (Miocene); 5: Carbonate platform rocks (Upper Jurassic-Cretaceous); 6: Scarp and basin chert-carbonate rocks (Upper Jurassic-Cretaceous).

Lecce, which is constituted by 97 municipalities, the population of which is equal to 787 825 inhabitants (Table 1) (Istat, 2001).

Several surveys have been undertaken to detect the chemical-physical-bacteriological characteristics of Apulian groundwater; the most important surveys have considered the coastal springs (Cotecchia & Tulipano, 1989) and wells of the Apulian groundwater monitoring system (Cotecchia & Polemio 1998, 1999). As part of their research, the IRPI has carried out their own surveys in the wells and springs mentioned above, until the end of 2003.

Groundwater heights of the Salento are less than 4–5 m a.s.l. The Salento groundwater divide is located along the SE–NW axis, parallel to the Ionian and Adriatic coastlines, with piezometric gradient generally equal to 0.2–0.3%.

A deep limestone aquifer can be distinguished in the whole Salento area where main shallow aquifers can be locally observed too, mainly composed of calcarenite and secondary sands and conglomerates. The groundwater flow in the limestone aquifer, considered hereinafter, is generally unconfined.

METHODOLOGICAL FRAMEWORK

In order to define the temporal–spatial evolution of coastal environmental processes related to groundwater resources, some indicators for decision makers were designed to assess the environmental pressure caused by human activity, the aquifer conditions or state, and the anthropic response to correct undesirable situations. This indicator selection will allow a temporal follow-up of the evolution of groundwater and integrate hydrogeological and social aspects, with respect to what was agreed on in Chapter 18, Section 2 of Agenda 21 (UNCED, 1992), in the mission statement of the Dublin Conference (ICWE, 1992) and Objective 7 of the Millenium Development Objectives (UNDP, 2003).

The design and use of indicators has been recently called for to be used in environmental and ecological monitoring and in the general assessment of environmental sustainability at local, national and international scales (Berger & Iams, 1996). Environmental indicators are variables with a social meaning attached to that of their own scientific entity, and whose aim is to briefly describe the interests and preoccupations of society with regard to the environmental evolution and coherently contribute to the decision-making process.

There is a wide range of environmental indicators (OECD, 1993; Cendrero & Fischer, 1997, Cendrero, *et al*. 2001), and most of them are useful to decision makers and are designed to assess: (a) environmental pressure caused by human activity; (b) evaluated environmental conditions or state; and (c) anthropogenic response to correct undesirable situations.

Groundwater quality represents a special case for indicators due to the speed of changes, the natural and anthropogenic origin of contamination sources, and the relevance of involved ecosystems, especially in the case of coastal aquifers.

In order to define the coastal environmental processes related to groundwater resources, some indicators for decision makers and a quality classification method are discussed in the case of the two selected coastal aquifers. For the first issue, a set of indicators for pressure, state and response were selected taking account their relevance

Table 1 Pressure indicators in 2000 for the two study areas.

Indicators	Mar del Plata	Salento
Population (10^3)	564.1	787.8
Urban area (km^2)	150	235.7
Population density (inhab/km^2)	3384	3342
Urban population (%)	90	90
Annual exploited volume (10^6 m^3)	97.6	91.0
Summer exploited volume (%)	37	n.a.
Daily water supply (L/inhab)	539	345
Population lacking water supply (%)	20.8	0.0
Population lacking sewage (%)	27.1	39.3
Irrigated areas (km^2)	141	291
Official urban damping (km^2)	1.2	n.a.*
Annual waste weight (10^3 ton)	255.5	374.3

n.a.: data not available.
* 1721m^3 annual authorized volume.

Table 2 State indicators in 2000 for the two study areas.

Indicators	Mar del Plata	Salento
Annual recharge (mm)*	198	300*
Wells <0 m a.s.l. (%)	14	0
Minimum piezometric level due to discharge (m a.s.l.)	–2.9	n.a.
Wells with Cl > 200 mg/L (%)	3	41
Max. chloride conc. (mg/L)	366	1610
Wells with NO3 > 45 mg/L (%)	18	1
Bacteriologically polluted wells (%)	> 83	13

* mean annual value, in the period 1930–2005.
n.a.: data not available.

Table 3 Response indicators in 2000 for the two study areas.

Indicators	Mar del Plata	Salento
Total wells *	310	20 369
Working wells	255	≈ 20 369
Abandoned wells	55	n.a.
Jurisdictional organization	Municipal	Public company and Municipal
Annual budget (US$/inhabitant)	30	n.a.
Cost of water systems (US$/m3)	0.10	1.00(**)
Staffing (employer/1000 inhabitant)	1.2	n.a.
Environmental regulations	Provincial Laws Local regulation on cesspools Register of well constructors Mechanisms of control Master Plan 2006–2016	European, national and regional regulations. Groundwater discharge managed on the basis of the regional Water quality recovery plan of 1981–1983 and the Protection Plan of 2007

* Private and domestic wells are included in the case of Salento.
** mean value.
n.a.: data not available.

and data availability (Tables 1–3). The year 2000 was used as a date of comparison. For the second one, the selected quality classification method is defined considering a shared and quite standard approach, as described by an Italian law (D.L.152/99) which applies to some European Directives (1991/271 and 1991/676). This approach could be easily modified to consider the application of European Water Framework Directive 2000/60, and the proposed European Directive on the protection of groundwater against pollution. The approach distinguishes two groups of parameters—basic and additional (Tables 4 and 5). They have been selected based on those suggested by law, and by considering the nature of pollution sources which are typical of Apulian and Mar del Plata groundwater. The so called chemical classes, from 1 to 4 in decreasing quality order, can be described as follows: Class 1, null or negligible anthropogenic impact, high groundwater quality; Class 2, low anthropogenic impact, long-term sustainable impact, good groundwater quality; Class 3, valuable anthropogenic impact, good groundwater quality subject to degradation risk; Class 4, marked anthropogenic impact, low groundwater quality; Class 0, null or negligible anthropogenic impact but with at least a parameter able to attain Class 4.

The mean concentration of each basic or additional parameter is used for the quality classification in each surveying period.

The quality classes are defined according to classes defined by Table 4 for each basic parameter, but also based on the threshold value of Table 5. The concentration of one or more pollutants higher than the thresholds of Table 5 determines the classify-cation in Class 4 otherwise the water is classified considering the parameters of Table 4. The final classification of the water sample is equal to the worst class selected by the whole set of basic and additional parameters. If the concentration of a parameter is high enough to attain Class 4 but its origin is natural, it is assigned Class 0.

Table 4 Quality classification on the basis of basic chemical parameters, Salento (D.L.152/99).

Parameter/Class	1	2	3	4
SEC (μS/cm at 20C°)	≤400		≤2500	>2500
Cl	≤25		≤250	>250
Mn (μg/l)	≤20		≤50	>50
Fe (μg/l)	≤50		≤200	>200
NO_3 (mg/l)	≤5	≤25	≤50	>50
SO_4 (mg/l)	≤25		≤250	>250
NH_4 (mg/l)	≤0.05		≤0.5	>0.5

SEC or specific electrical conductivity.

Table 5 Threshold of additional chemical parameters, Salento (D.L.152/99).

Parameter	μg/L
Arsenic	≤10
Cadmium	≤5
Chrome	≤50
Nitrite	≤500
Lead	≤10

The presence of significant concentrations of additional parameters lower than the threshold, except in the case of natural presence, is, however, a negative signal and unacceptable in terms of groundwater quality. In this case, actions to prevent further quality degradation, removing the pollution causes and reducing the pollution concentrations should be adopted.

RESULTS AND DISCUSSION FOR THE STUDY AREAS

The analysis and comparison of the pressure indicators (Table 1) for both cases shows very important similarities to population density, urban population and annual exploited volume; there are approximate similarities considering total population, population lacking sewage, annual waste weight and urban surface. Finally, marked differences were detected in daily water supply, population lacking water supply and irrigated areas.

The analysis of the state indicators (Table 2) for both cases allows us to identify some interesting issues in spite of the strong hydrogeological differences. It is notable how nitrates, chlorides and the biological pollution determine the present conditions. Whereas, in the case of Mar del Plata, nitrates and the biological pollution are more significant than chlorides, Salento shows the opposite effect. Also, there is a piezometric drawdown in Mar del Plata that is negligible in the case of Salento, if, in the latter case, the piezometric and groundwater quality data are available only for wells of the monitoring network, wells not used to discharge groundwater. For this reason the minimum piezometric level due to discharge is not available in the case of Salento. The percentage of wells hit by bacteriological pollution has been determined considering the bacteriological data from water samples taken from each of the wells and comparing these data with Italian drinking water criteria.

Response indicators (Table 3) show some remarkable differences considering the ratio of working wells to groundwater supply, the cost of running-water systems and the environmental regulations that have been applied. The present jurisdictional framework is quite similar in both cases.

In the quality assessment of Mar del Plata groundwater, 399 analyses of samples collected from 1995 to 2005 have been considered (Table 6). There is no quality class variation in chlorides between 1995 and 2005, 97% of the wells remaining in Class 3 and 3% in Class 4 during this period. On the other hand, nitrates (Fig. 3) show that the class is increasing in wells located in the suburban areas with high population density.

Table 6 Statistics of classification results for Mar del Plata.

	Main parameters						Others parameters
	SEC	Cl	Fe	NO3	SO4	NH4	NO2
PD (%)	100	100	55	100	100	94	100
Class1 (%)	0	0	48	6	46	96	
Class 2 (%)				53			
Class 3 (%)	99	97	29	17	54	4	
Class 4 (%)	1	3	23	24	0	0	1

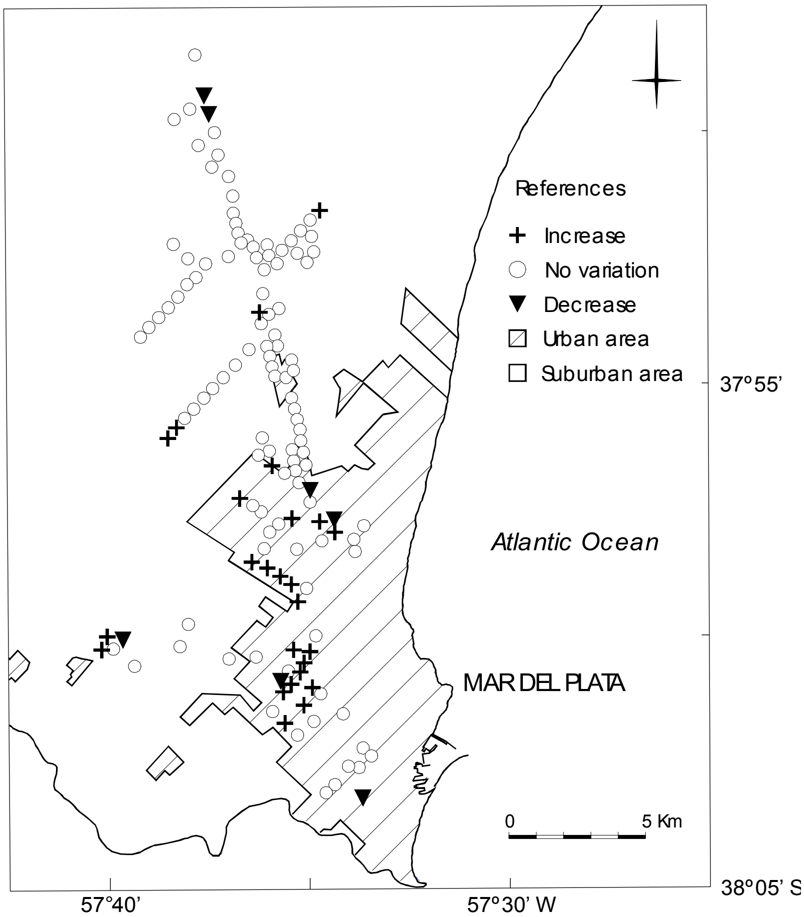

Fig. 3 Quality class variation of nitrate in 2005 compared to 1995 for Mar del Plata.

There is no class variation in rural areas and suburban areas with low population density, and finally, the quality class has decreased in few isolated wells.

The analysis of the data set from the monitoring network surveys has found the best quality groundwater is in some portions of the recharge area of Salento. These areas are located, as in the case of the 1984 situation (Apulia Regional Administration, 1984), inland, where the anthropogenic activities are not relevant. The extent of these areas appears to be decreasing since 1984.

The latest IRPI survey has been designed to characterize the quality modification of groundwater along the flow path from recharge areas to natural discharge areas along the coast line. For this purpose some wells and springs have been selected from that zone to represent the groundwater quality there.

The temperature, the specific electrical conductivity, pH, Eh, and the concentrations of ammonia, nitrite, nitrate, chloride, manganese, iron, mercury, lead, arsenic, cadmium zinc, arsenic and chromium of the groundwater have all been measured on site and in the laboratory by chemical analyses. The laboratory determination of the concentration of total coliforms, faecal coliforms and faecal streptococci permits quantifying the bacteriological quality of the groundwater. The high chloride concentration can be observed also far inland from the coast. The widespread presence of the saltwater has been caused by high rates of well discharge that have lead to seawater intrusion.

Pollution linked with nitrates in the study area falls within the limits established by the law. The sampled water presents a high level of bacteriological pollution determined mainly by total coliforms and secondly by faecal coliforms.

Wells located in core portions of recharge areas present the highest groundwater quality, of Class 1 or 2. In other portions of the aquifer, the predominant class is 4. In those portions belonging to the most polluted class, pollution is determined by specific electric conductivity and chloride, two correlated parameters, where the chloride content depends on the effect of seawater intrusion in these hydrogeological conditions. The parameters determining which wells belong to Class 4 are: specific electric conductivity, chloride, sulphate, ammonia, nitrate and lead.

Groundwater quality worsens along the flow paths from recharge areas to coastal discharge areas, surface water bodies, the hydrographic network, narrow lagoons, and the sea. This spatial trend is not continuous and homogeneous, due to local hydrogeological and, mainly, anthropogenic factors, since many urban areas are located around these areas. A greater spatial variability of quality is observed in Salento due to the higher aquifer vulnerability and density of villages, towns and areas of anthropogenic activities. As can be observed by the class variation of 2000 with respect to 1995, a huge quality worsening is observed in terms of chloride (Fig. 4(a)) and nitrate concentrations (Fig. 4(b)), especially in the northern part of the area.

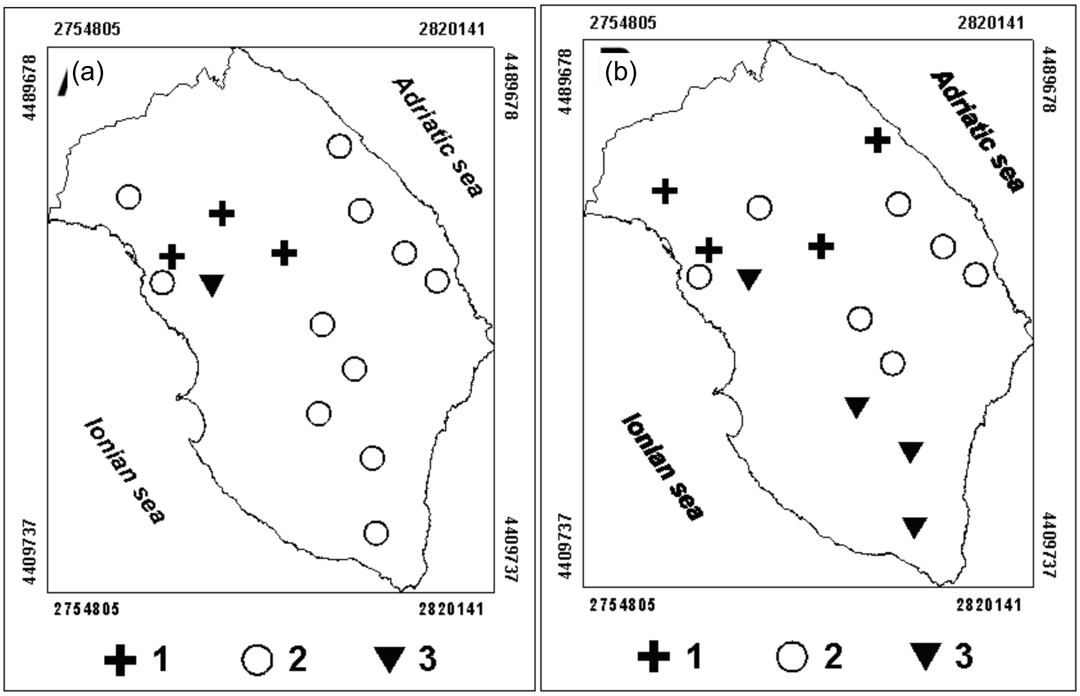

Fig. 4 Quality class variation of (a) chloride and (b) nitrate in 2000 compared to 1995 for Salento [1: class increase; 2: class unchanged; 3: class decrease].

CONCLUSIONS

The use of indicators of pressure, state and response to analyse groundwater conditions allows us identify several similarities between the Mar del Plata and Salento areas, in spite of the marked hydrogeological differences. The temporal analysis of the joint evolution of these indicators appears as the most effective tool for decision making; nevertheless, the combination of these indicators into one single quality index that will lead to the better adjustment of management policies is still under discussion. Some state indicators should constitute requisites of special value, since they show whether water is drinkable or not.

In the case of Mar del Plata, it can be appreciated that, despite the critical political and economic context, there have been satisfactory answers to the problems and demands originated around the issue of the groundwater resource. The application of quality class variation is new in Argentina and appears to be an efficient monitoring tool. The seriousness of the effects of natural and artificial phenomena which are highly relevant for the protection of the groundwater resources of Salento has been highlighted. Notwithstanding the complexity of the phenomena that threaten groundwater quality, the proposed quality classification clearly highlights that quality degradation hazards have already became a reality. High quality groundwater can now be found in inland and narrow Salento zones. Groundwater flows from these zones, which are hydrogeologically a portion of recharge areas, to the coastal areas under the huge effect of a progressive anthropogenic pollution.

Groundwater is loaded with pollutants that reach coastal springs without appreciable attenuation, due to the karstic nature of the aquifers. In the case of submarine springs, contamination is reduced by an appreciable dilution. Where spring outflow becomes inflow for lagoons or valuable humid habitats, the ecological equilibrium is subject to serious risks due to continuous degradation of groundwater quality.

REFERENCES

Apulia Regional Administration (1984) Piano Regionale Risanamento delle Acque. *Boll. Uff. Regione Puglia* **XV**, 57.

Berger, A & Iams, W. (1996) *Geoindicators*. Balkema, Rotterdam, The Netherlands.

Bocanegra, E. M., Martínez, D. E., Massone, H. E. & Cionchi, J. L. (1993) Exploitation effect and salt water intrusion in the Mar del Plata aquifer, Argentina. Study and modeling of salt water intrusion into aquifer. In: *Proc. of XII Salt Water Intrusión Meeting* (ed. by E. Custodio & A. Galofre), 177–191. Centro Internacional Métodos Numéricos-Universidad Politécnica de Cataluña.

Bocanegra, E. M., Massone, H. E., Martinez, D. E., Civit, E. M. & Farenga, M. (2001a) Groundwater contamination: risk management and assessment for landfills in Mar del Plata, Argentina. *Environ. Geol.* **40**(6), 732–741.

Bocanegra, E. M., Villamil, M. & Massone, H.E. (2001b) Aquifer vulnerability and bacteriological contamination hazard on Mar del Plata (Argentina) suburban area. In: *New Approaches Characterizing Groundwater Flow* (ed. by K. Seiler & S. Wohnlich) (Proc. XXXI IAH Congress), **1**, 457–461. Balkema, Rotterdam, The Netherlands.

Bocanegra, E. M., Martínez, D. E., Massone, H. E. & Benavente, M. A. (2002) Quantitative studies in coastal hydrogeology in Mar del Plata, Argentina. In: *Aguas Subterráneas y Desarrollo Humano. Págs* (ed. by E. Bocanegra *et al.*) (Proc. of XXXII IAH & VI ALHSUD Congress "Groundwater and Human Development", Mar del Plata, Argentina), 389–396. ISBN 987-544-063-9.

Cendrero, A. & Fischer, D. W. (1997). A procedure for assessing the environmental quality of coastal areas for planning and management. *J. Coastal Res.* **13**(3), 732–744.

Cendrero A., Francés, E., Panizza, M., Fabbri, A., Recatalá, L., Fermán, J. L., Fischer, D. W., Quintana, C., Latrubesse, E., Tecchi, R., Cantú, M. P., Hurtado, M. A. & Cecioni, A. (2001) A conceptual background and methodological approach for assessing and monitoring environmental quality. III Reunion de Geología Ambiental y I del Area del Mercosur. Mar del Plata. Published on CD.

Colucci, V., Limoni, P. P. & Serravezza, C. (1998) La rete di controllo idrometrografico e qualitativo delle falde idriche pugliesi. *Acque Sotterranee* **59**, 55–61.

Cotecchia, V. (1981) Methodologies adopted and results achieved in the investigations of seawater intrusion into the aquifer of Apulia (Southern Italy). In: *Salt Water Intrusion Meeting* (Hannover, 15–18 October 1981), 1–68.

Cotecchia, V. & Polemio, M. (1997) L'inquinamento e il sovrasfruttamento delle risorse idriche sotterranee pugliesi. In: VI Workshop del Progetto Strategico *Clima, Ambiente e Territorio nel Mezzogiorno* (Taormina, Italy, December 1995), **I**, 447–484.

Cotecchia, V. & Polemio, M. (1998) The hydrogeological survey of Apulian groundwater (Southern Italy): salinization, pollution and over-abstraction. In: *Proc. Int. Conf. on Hydrology in a Changing Environment* (British Hydrological Society, Exeter, UK, 6–10 July 1998), **II**, 129–136. John Wiley & Sons, Chichester, UK.

Cotecchia, V. & Polemio, M. (1999) Apulian groundwater (Southern Italy) salt pollution monitoring network. *Flemish J. Natural Science*, Ghent, Belgium, 197–204.

Cotecchia, V. Grassi, D. & Polemio, M. (2004) Carbonate aquifers in Apulia and seawater intrusion. In: *Some Engineering Geology Case Histories in Italy* (32nd IGC), 1–16.

Cotecchia, V. & Tulipano, L. (1989) Le emergenze a mare individuate anche con tecniche di telerilevamento, come vettori di carichi inquinanti dagli acquiferi carbonatici e carsici pugliesi all'ambiente costiero. *I Workshop Progetto Strategico Clima Ambiente e Territorio nel Mezzogiorno* (Taormina, Italy), 133–144.

Dalla Salda, L. & Iñiguez, A. (1978). La Tinta: Precámbrico y Paleozoico de Buenos Aires. Procc. VII Congreso Geológico Argentino, Actas:1. 539-550.

ICWE (International Conference on Water and the Environment) (1992) *Development Issues for the 21st Century*. The Dublin Statement and Report of the Conference, Dublin, Ireland, 26–31 January 1992. World Meteorological Organization, Geneva, Switzerland.

Istat (Istituto Nazionale di Statistica) (2001) Popolazione e movimento anagrafico dei comuni: anno 2000. (Annuario n. 13).

Martínez, D. E., Bocanegra, E. M. & Cionchi, J. L. (1996) Modelación hidrogeoquímica de procesos de mezcla. Su aplicación a casos de estudio en el acuífero de Mar del Plata. *Serie Correlación Geológica* **11**, 69–80.

Martínez, D. E., Massone, H. E. & Bocanegra, E. M. (2005) Groundwater salinization in the harbour area graben in Mar del Plata, Argentina. Hydrogeochemical perspective. *IGME, Serie Hidrogeología y Aguas Subterráneas 15,* 585–595. ISBN 84-7840-588-7.

Mascioli S., Martinez D. & Bocanegra E. (2005). Determinación del coeficiente de partición de Zn en sedimentos loessicos y su utilización en la simulación de transporte reactivo. In: *IV Congreso Argentino de Hidrogeología* (Río Cuarto, Córdoba, 25 al 28 de octubre de 2005), Actas I: 221–230. ISBN 950-665-346-1.

Massone, H., Del Rio, J.L., Fajardo, D., Cionchi, J., Martinez, D. & Bocanegra, E. (1993) Los Residuos Sólidos Domiciliarios del Partido de General Pueyrredon (Provincia de Buenos Aires) desde una Perspectiva Geológico-Ambiental. Parte I: Aplicación de la Cartografía Geocientífica a la Selección de Sitios de Disposición Final. *XII Congreso Geológico Argentino, Mendoza*, Actas VI, 303–310.

Massone, H., Martinez, D., Cionchi, J. L. & Bocanegra, E. M. (1994) Procesos de contaminación del acuífero de Mar del Plata, Argentina: diagnóstico y pautas de prevención y control. In: *II Congreso Latinoamericano de Hidrología Subterránea* (Santiago, Chile), vol. 1, 81–95.

Massone, H., Martínez, D. E., Cionchi, J. L. & Bocanegra, E. M. (1998) Suburban areas in developing countries and its relation with groundwater pollution. Mar del Plata (Argentina) as a case study. *Environ. Manage.* **22**(2), 245–254.

OECD (Organisation for Economic Co-operation and Development) (1993) Environmental indicators for environmental performance reviews. OECD, París.

Polemio, M. (2000) Degradation risk owing to contamination and overdraft for Apulian groundwater resources (Southern Italy). In: *Water Resources Management in a Vulnerable Environment for Sustainable Development* (ed. by K. Andah), 185–194. UNESCO - International Hydrological Programme, Grifo Publishers, Perugia, Italy.

Polemio, M. & Limoni, P.P. (2001) L'evoluzione dell'inquinamento salino delle acque sotterranee della Murgia e del Salento. *Memorie della Società Geologica Italiana* **56**, 327–331.

Ruíz Huidobro, O. & Tofalo, O. R. (1975) La intrusión de agua de mar en acuíferos litorales. Su control en Mar del Plata (República Argentina). *VI Cong. Geol. Arg*., Actas, 515–523. Buenos Aires.

Sala, J. M., Hernández, M., González, N., Kruse, E. & A. Rojo (1980) Investigación geohidrológica aplicada en el área de Mar del Plata. Convenio Obras Sanitarias de la Nación - Universidad Nacional de La Plata. V Tomos, (unpublished).

UNCED (United Nations Conference on Environment and Development) (1992) *Report of the United Nations Conference on Environment and Development*, Rio 1992.

UNDP (2003) *UN Millennium Declaration*. Millennium Development Goals.