XXXVIII IAH Congress

Groundwater Quality Sustainability
Krakow, 12–17 September 2010

Extended Abstracts

Editors:
Andrzej Zuber
Jarosław Kania
Ewa Kmiecik

University of Silesia Press 2010

abstract id: **287**

topic: **1**
Groundwater quality sustainability

1.4
Groundwater quality and agriculture

title: **Agricultural waste management and groundwater protection**

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keywords: intensive agriculture, agricultural wastes, groundwater pollution

INTRODUCTION

The largest surface area of greenhouses in Spain covers 30.000 ha and generates some 1,500 million euros each year (Fundación Cajamar, 2006). This intensive agriculture produces around 770,000 t y^{-1} of plant waste. For a long time, this plant waste was burnt or else tipped in the countryside without any special precaution. Over the last two decades, a significant proportion is recycled, separating the plastic waste and making compost with the plant waste. The problem of elimination or recovery and recycling is common to all agricultural areas in the world.

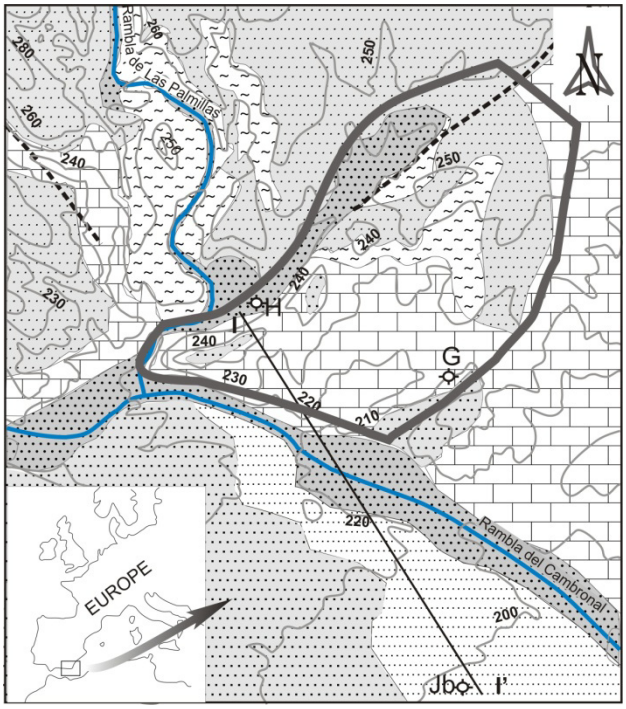

Figure 1. Location of agricultural waste treatment plant and sampling points (I-I': cross-section in fig. 2).

The solid agricultural waste treatment plant that forms the subject of this study is located east of Almería (Figure 1). It covers nearly 4,000 ha and takes some 120,000 t annually of mixed agricultural waste consisting of plant waste with rope, bags, fruit waste, wires from the greenhouse structures, soil attached to plant roots and plastic from the irrigation tubes (Callejón-Ferre et al., 2009). It produces 70 % biomass, which contains 14 % humus, 12 % compost and vermicompost and 12 % inert material. Leachate is stored in impermeable (lined) ponds, although other parts of the site are not lined, including the entire area where the plant waste is stacked, as well as small watercourses and puddles and ponds.

Though the climate in this area is semiarid, rainfall can be intense. Such intense rainfall generates leachate that infiltrates directly into the ground or creates surface runoff that drains into the nearest nearby rambla (dry watercourse), from where it too infiltrates. These leachates have elevated concentrations of organic material, metal and metalloids, depending on the treatments that have been applied. They are highly polluting if there are no mechanisms to contain them within the plant (Sara, 2003).

GEOLOGICAL AND HYDROGEOLOGICAL SETTING

The study area lies within the Betic Cordillera. Outcrops include pre-orogenic and post-orogenic terrains. The pre-orogenic rocks belong to the Alpujarride Complex and comprise micaschists, phyllites, quartzites and recrystallized dolomites at the top. This series is about 400 m thick. The oldest post-orogenic outcrops date from the Tortonian. The most abundant facies are the calcarenites of a reef talus. The Pliocene is represented by sands, as well as yellow calcarenites, marls and sandy marls. Overlying these are Plioquaternary marine conglomerates and sandstones. Then come some Pleistocene alluvial deposits and lastly, gravels, sands and silts of the present-day ramblas.

Triassic limestones and dolomites, Miocene calcarenites and sands, Plioquaternary conglomerates and sands, as well as the alluvia and riverbed deposits all behave as aquifers, which conform to a relatively simple geometry. A simplified scheme of their characteristics is given in the section in Figure 2. The transmissivity of the Alpujarride deposits is 9000 m^2/day (IGME, 1982).

The dominant flow direction is N-S. In the area of the treatment plant, the aquifer is unconfined and varies in thickness from 0 to 160 m, with a saturated zone of 30-35 m, on average. Transmissivity varies from 10 to 900 m^2/day and the effective porosity could be 15-20 % (IGME, 1982). The study borehole furthest from the treatment plant along the direction of the groundwater flow is denominated Jb (see Figure 2). Test pumping in this borehole at a rate of 12.7 L/s, resulted in a drop in water level of 1.74 m after 300 minutes. The value of transmissivity obtained was 1000 m^2/day, while the storage coefficient was 0.08.

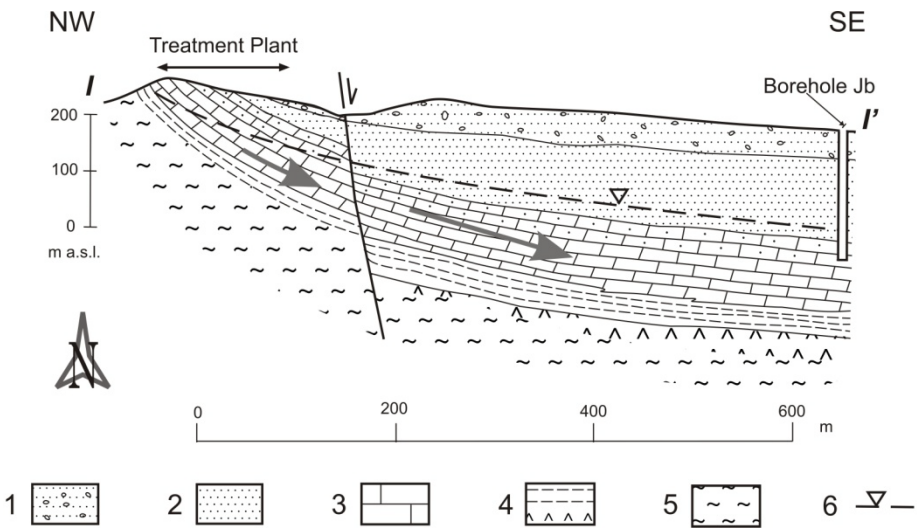

Figure 2. Hydrogeological cross-section. 1: Conglomerates, sands and clays (continental Pleistocene), 2: Sands, sandstones and calcarenites (Pliocene): 3: Calcarenites from a reef talus (Miocene), 4: Sandstones, sandy marls, limestones and reef calcarenites. (Messinian-Andalusian), 5: Alpujarride Substrate (Triass). 6: Piezometric level.

a)

b)

Photos 1 and 2. Aspect of the accumulated plant wastes, showing the leachate emerging in the foreground (a) and a lined leachate pond (b).

The main inflow to the aquifers comes from direct infiltration of rainfall and surface runoff. Rainfall is scarce – generally less than 250 mm/year, which means that recharge rarely exceeds 20% of the rainfall. The main outflows are the pumped abstractions from boreholes. The pumped abstractions have exceeded the inflows to the aquifer for many years, and this has led to a continuous drop in water levels, as well as salinization of many sectors, with the consequent abandonment of wells and farmland.

MATERIALS AND METHODS

The first step was to overlay a 1:10,000 map on an aerial photo of the entire study area. Subsequently, test pumping was carried out (November 2008) and water samples were taken both from the pumped well and from the two boreholes located inside the treatment plant. Electrical conductivity, pH and temperature were measured *in situ,* while the major and minor ions, TOC, COD and BOD_5 were analysed later in the laboratory. Three samples of leachate were also taken and stored at 4 ºC for subsequent analysis in the Bioclinical Analytical Laboratory of Almería.

RESULTS AND DISCUSSION

Physico-chemical characteristics of groundwater

Mean water temperature was 25.8 ºC, electrical conductivity oscillated between 2300 and 3000 microS/cm and pH was slightly acidic (7.2). The Piper diagram (fig. 3) shows the water facies is basically sodium bicarbonate-chloride, which indicates the presence of chloride salts in the aquifer matrix. These salts may be derive from evaporites intercalated in the deposits, or from the lixiviates from salts remaining in Miocene marine deposits higher up in the stratigraphic column.

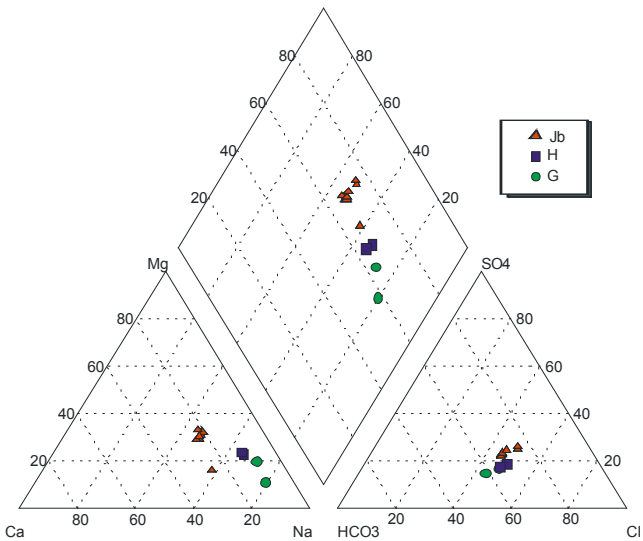

Figure 3. Piper diagram of the groundwater samples.

Heavy metal concentrations in the groundwater allow characterization of the possible pollution of the aquifer. These heavy metals come from plant remains, compost and fertilizers (Amlinger et.al. 2004). The concentration of iron increases considerably between borehole H (11 µg/L) and borehole Jb (more than 600 µg/.L). Manganese concentrations also increase from a mean of 13.4 µg/L in boreholes H and G to 327 µg/L in Jb. The contents of Ba, Ti and Ni also increase, though less sharply (table 1). The marked reducing medium in the vicinity means that the solubility of the metals is substantially raised above their limited solubility in an oxidising medium. The pollutant plume, indicated by the content of organic material and certain minor ions, increases along the direction of groundwater flow, *i.e.* towards borehole Jb.

Table 1. Analysis of groundwater chemistry during the pumping test Leachates.

	H1	H2	G1	G2	Jb1	Jb2	Jb3	Jb4	Jb5	Jb6	Jb7	Jb8
NH_4 mg/L	0,4	0,4	1,0	0,9	8,8	8,6	7,0	8,5	8,0	7,5	7,5	7,5
Ti µg/L	0,2	0,3	0,3	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4
V µg/L	0,6	0,7	0,9	0,9	80,8	0,9	1,0	1,1	1,1	1,1	1,0	1,1
Al µg/L	>10	10,4	>10	>10	>10	0,9	>10	>10	>10	>10	>10	>10
Mn µg/L	10	9	17	17	306	310	311	308	313	317	322	410
Ni µg/L	<5	<5	<5	<5	5,2	5,6	6,5	7,2	7,8	7,1	8,1	9,6
Zn mg/L	<0,01	<0,01	<0,01	<0,01	<0,01	0,03	0,02	0,03	<0,01	0,03	0,03	0,03
Ag µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	3,57	1,34	1,20
Sn µg/L	0,04	0,01	0,02	0,02	0,006	0,004	0,006	0,004	0,004	0,005	0,004	0,003
Ba µg/L	15	19	22	22	52	58	57	59	58	58	58	57
U µg/L	2,0	2,1	0,5	0,4	2,4	2,5	2,6	2,7	2,8	2,8	2,9	2,9
Fe µg/L	11	19	66	72	648	667	313	577	253	388	379	393
TOC mg/L	27	29	30	29	29	31	31	37	32	30	27	22
DQO mg/L	27	35	29	26	27	23	22	27	24	50	49	18
DBO_5 O_2/L	9,5	10,5	9,5	9,0	9,5	9,5	10,0	10,5	9,0	8,5	9,0	8,5

Some of the leachates generated in the treatment plant are stored in ponds with an impermeable liner, while other outflows are from unlined surfaces, such as the small watercourses, channels and puddles, as well as the compost and vermicompost storage area. The leachate arises due to the intrinsic humidity of the organic matter, the composting process and, in very wet years, from rainfall. It is an aqueous solution charged with substances in solution and in suspension, and is highly polluting. It penetrates to the saturated zone of the aquifer and from there is carried with the groundwater flow of the aquifer. The majority of the leachate is generated over the aquifer formations of Mio-Pliocene calcarenites, with a smaller volume of leachate generated over the impermeable phyllites. Some leachate also flows into nearby ramblas (dry streambeds) and eventually infiltrates through the rambla bed and into the groundwater flow.

According to the analysis of leachates taken from the containment ponds and from a small channel, average concentrations in major ions are highly elevated, particularly chloride (8100 mg/L), sulphate (1650 mg/L), HCO_3^{-1} (13800 mg/L) and sodium (2080 mg/L). Mean TOC is also high (2300 mg/L), BOD_5 (24 g O_2/L) and DQO (63 g O_2/L), as is NH_4 (370 mg/L) and SiO_2 (300 mg/L). Concentrations of the minor ions Fe, Cu, Zn, As, Ni, Mo Cr, Cd, B, Ba are also elevated. The behaviour of the heavy metals present in residues is important from the point of view of envi-

ronmental legislation, in terms of the criteria for determining increases in soil residues and the prevention of soil pollution (Robin et al., 2008).

Mean concentration of TOC in the borehole water was close to 30 mg/L. Mean DQO and BOD are 29.5 and 9.5 mg/L, respectively. During the pumping tests, there was a noticeable small in the water taken from the Jb borehole – possibly due to the decomposition of organic material. Nitrate concentrations from the three boreholes were low (0.3 to 2.15 mg/L), probably as a result of the reducing medium.

The degree of groundwater pollution varies from one well to another, as is clearly shown by the NH_4^+ content. Boreholes H and G yielded a mean of 4.42 mg/L, while in Jb the value was 7.9 mg/L. All of these values are extremely high for groundwater.

FINAL CONSIDERATIONS

The study area presents clear evidence of organic pollution, whose nearest point of origin is the Greenhouse Waste Treatment Plant. In particular, the finger points to the migration of leachates from unlined sites within the treatment plants, which are therefore not isolated from the area's main aquifer.

A primary corrective measure would be to line the entire plant waste storage and processing area, and install a leachate treatment station. In addition, an adequate aquifer decontamination system should be in place, even though this latter option would be very costly.

REFERENCES

Amlinger M., Pollk M. and Favoino E., 2004: *Heavy metals and organic compounds from wastes used as organic fertilisers*. Env.A.2. ETU/2001/0024. Final Report to DG Enviroment. Brussels.

Fundación Cajamar, 2006: *Analysis of the Harvest Time Fruits and Vegetables of Almería.* Ed. Cajamar (in Spanish).Almería. 22 p.

IGME, 1982: *Hydrogeological study of Campo de Níjar.* 12 vol. Servicio de documentación del ITGE (in Spanish).

Callejón Ferre A.J. and López Martínez J.A., 2009: *Briquettes of plants remains from the greenhouses of Almería (Spain).* Spanish Journal of Agricultural Research 7(3), pp. 525-534.

Robin P., Ablain F., Yulipriyanto H., Pourchet A.M., Morvan T., Cluzeau D. and Morand P., 2008: *Evolution of non-dissolved particulate organic matter during composting of sludge with straw.* Bioresource Technology Vol. 99(1): pp. 142-156.

Sara M.N., 2003: *Site Assessment and Remediation Handbook*. Lewis Pub. Boca Raton. 994 p.

International Association of Hydrogeologists

AGH University of Science and Technology

2-vol. set + CD
ISSN 0208-6336
ISBN 978-83-226-1979-0