Water and Gas Emissions: Dynamics and Mutual Influences

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Abstract: This paper looks into the surfacing of mineral waters and/or gases, consisting mainly of CO_2, that occur in volcanic zones. Considering the origin and dynamics whereby such fluids are issued into the atmosphere, the mechanisms and factors characterizing and controlling their rising to the surface are examined with special emphasis on the water-gas interactions. The case of mineral water extraction through wells as a result of the expansion of the gas that is present in the water is taken into account: from the behaviour in time and during significant events in a mineral water and CO_2 field measures to optimise exploitation are suggested. Considering, too, the factors controlling the diffusion of the gas, the risks due to accumulations where such fluids are exploited and in the areas where they emerge from the ground are highlighted. The safety measures that could be adopted are either to prevent the gas escaping from the ground from causing damage, or prevent the gas from being issued into the air. As to this latter solution and taking into account the Lake Nyos catastrophe, it is proposed the exploitation the underground fluids that make their way to the surface, thus decreasing their underground pressure that causes their rising to the surface.

1 INTRODUCTION

Hot waters, warm mineral waters and non-fuel coming gases from underground deposits, consisting mainly of carbon dioxide, are among the underground fluids that are or could be exploited either to produce energy, if the enthalpy is sufficiently high, or to utilise some their components or to use them as they are. Such resources are usually exploited in geo-thermoelectric power plants, where electricity is obtained for the expansion of the geothermal fluid and from the condensation of its steam, or in condensation plants or in spas.

The risks incurred in these plants and spas are considerable given the presence of CO_2 and of other gases that are just as dangerous. Such risks however are not only associated with the exploitation plants but are present throughout the areas where such gases are naturally or accidentally present. It is therefore important to understand the mechanisms whereby the mentioned fluids make their way to the surface and how they spread throughout the atmosphere, and also to know the parameters that control such mechanisms so as to be able to take action to limit the presence of the gas in the environment enough to eliminate or at least sufficiently attenuate the risks, also by means of a rational exploitation of such fluids. Indeed, the latter could be a useful solution with a view to the safety of the areas where gas emissions occur systematically or by accident: by piping the fluids to the utilizer plants, the pressure in the zones that are to be protected step by step decreases and the gas emissions weaken and ultimately disappear. And indeed the exploitation in Southern Tuscany of the carbon dioxide of a field where CO_2 was prevalent has led to the disappearance of CO_2 emissions which used to occur, occasionally in deadly concentrations, along the course of a nearby river (Sammarco 1996).

The fundamental aim of this paper is to suggest that the exploitation of gas and/or steam fields is a basic form of prevention against harmful gas emissions.

2 ORIGIN

All over the world, high heat flow zones, young or active volcanoes, CO_2 emissions, and mineral and warm water springs are all normally concentrated in seismic areas, represented by a narrow circum-Pacific belt and by a broad area in central and southern Europe and Asia Minor (Barnes et al., 1978). As a result of the considerable tectonic activity occurring in these areas fractures and faults are generated along which the geothermal fluids that are not directly channelled along the volcanic vents can make their way to the surface.

The rise to the surface of gases, with the main gas being carbon dioxide, and hot mineral water may be explained as the consequence of magma consolidation, typical of volcanism. Besides silicate components, the magma contains, in the form of solutions, volatile components such as carbon dioxide, hydrogen, hydrogen fluoride, and hydrogen chloride. As the magma consolidates, such components are released in the gas phase. Carbon dioxide is released in larger amounts than the other components since it is not very soluble in the magma. Once it is released from the magma the gas rises to the surface by travelling across permeable formations, that are either entirely or partially saturated with water or steam. The chemically active components in the formations react with the transiting gas.

As carbon dioxide is not very reactive and it is soluble in water, it is the component of the magma that has greater probability than the other gases of reaching the surface on its own or dissolved in the water that it encounters along its path, and that can saturate (Sigvaldason, 1989) as well at pressures that are considerably greater than atmospheric pressure.

It is also quite likely however that the water encountered by the carbon dioxide is not only juvenile water, but above all rain water that may however be mixed with the former. The marked dependence of warm mineral water flows on rainfall, as often reported, confirms the mainly meteoric origin of such waters. In actual fact rainwater may acquire the chemical components of mineral waters or reach the temperature of warm spring waters if it remains for a sufficient amount of time in contact with soluble rock, in evaporitic formations for example, or in zones where the geothermal flow is high.

The marked prevalence of carbon dioxide in gas emissions, in some circumstances, could be due also to the development of CO_2, during the hydro-thermo-metamorphism processes, due to de-carbonization reactions favoured by the high temperatures present in the zones having a high geothermal gradient (Barberi et al., 1971).

On the other hand, the thermal nature of spa waters has been also assumed to be of thermo-chemical origin, namely due to the heat released as a result of exothermal reactions such as the hydration of anhydrite in gypsum (Burckhardt, 1947 & Trevisan, 1951). This assumption, which according to the authors themselves required further study, cannot be taken as a general rule, but it could be true in specific circumstances as in the case of intensely fractured anhydrite formations crossed by minimal water flows.

Instead, the assumption according to which heat is transferred to underground fluids by real heat sources has been confirmed. The peri-Tyrrhenian Apennine area for instance is particularly rich in hot springs and gas emissions (Duchi & Minissale, 1995) and is characterized by an extensive thermal anomaly at the regional level and at the local level as a result of the magmas that rise very close to the crust (Barberi et al., 1971).

3 DYNAMICS

Volcanic eruptions and surface emissions of geothermal fluids that are made to rise to the surface through wells so as to be able to exploit the energy they contain show how imposing the endogenous energy is. The effects of this energy can be seen also in other manifestations that are less conspicuous than the former, namely geysers and gas, steam and water and gas emissions, that make their way to the surface through pre-existing fractures or through purposely driven wells. Such effects can be assessed by analysing the mechanisms underlying each of these processes which in any case consist of an energy and mass flow.

A part of the energy that the fluid receives from the subsoil or from other sources is used for fluid motion which in turn may be the carrier of an exploitable energy.

It is not possible to correctly classify these emissions as it is not possible to take into account all of the factors that they depend on, but if account is kept only of the motor work that causes them, then the following can be said to occur:

- Gravity emissions of warm waters and/or mineral waters and gases that are heavier than air, that have reached higher elevations than those of the outlets;
- Fluid emissions due to the energy they receive as a result of gas expansion and/or steam expansion and/or condensation;
- Emission of fluids as a result of both the factors mentioned above.

As to the way to showing themselves, many types of emission can occur, there are many of them which range thenselves from a phreatic explosion and instantaneous irruption to a continuous and nearly steady emission and discontinuous emission.

Phreatic explosions occur when very hot fluids consisting of water in the liquid phase, where salts and gas substances are dissolved, come so close to the surface as to find themselves in a lithostatic pressure below boiling point. In these circumstances the increase in pressure due to vaporization determines the failure of the overburden and in some cases stones may even be hurled

(Marinelli, 1969). An example par excellence is the phreatic explosion that very likely caused the injection into Lake Nyos in Cameroon of gases accumulated in levels beneath the lake due to natural geothermal activity. The gas which issued from the lake killed over 1700 people (Barberi et al., 1989). Another instance is the phreatic explosion said to have occurred on the bottom of Lake Monoun, once again in Cameroon in 1984, which caused the death of 40 people (Tazieff, 1989) and another one in Dieng, Indonesia in 1979, where huge volumes of CO_2 were erupted from a dry crater and 127 persons lost their lives (Le Guern et al., 1982).

Figure 1a refers to an instantaneous irruption in the Boccheggiano mine, with the sudden release of 133,000 m^3 of CO_2 and the hurling of 3,600 kN of almost all finely ground phyllitic rocks, at the face of a ramp, following the explosion of a volley: having a specific weight greater than that of the air and given the geometry of the ramp, the CO_2 gas invaded the latter throughout its length, totally displacing the air and then, overflowing at its end, it back-flowed to the other parts of the tunnel at decreasing flows in time according to the trend shown in Figure 1a (Sammarco, 1991).

Phreatic explosions and sudden irruption may evolve into continuous or discontinuous emissions respectively of steam and gas and of gas.

Figure 1b refers to a CO_2 gas emission whose flow was strongly dependent on the atmospheric pressure and which occurred in an old gallery of the Selvena mine: atmospheric pressure variations typical of storms were simulated by stopping and starting the fans that ventilated the gallery; the results obtained are shown in figure 1b (Sammarco, 1984). In this case, being the pressure of the gas upstream from the outlet lower than twice the atmospheric pressure, the gas flow rate depended on the pressure according to the following approximated expression:

$$q_u = \Omega\left[2g\gamma(\gamma-1)^{-1} p_r \delta_r \left(p_{g/r}^{2/\gamma} - p_{g/r}^{(\gamma+1)/\gamma}\right)\right]^{1/2} \qquad (1)$$

where

q_u = gas flow rate discharged into the gallery, in N/s,
Ω = minimum discharge cross-section, in m^2,
g = gravitational constant in m/s^2,
γ = ratio specific heat of gas at constant pressure to specific heat of gas at constant volume,
p_r = pressure in the reservoir, in N/m^2,
δ_r = specific weight, in N/m^3, of the gas in the reservoir,
$p_{g/r}$ = ratio between the atmospheric pressure in the gallery and that in the reservoir.

This expression, among other things, shows that there is no two-way correspondence between atmospheric pressure and gas flow rate. This is explained by the fact that the pressure in the reservoir from which the gas comes, depends on the evolution of atmospheric pressure, unless the capacity of the reservoir can be approximately estimated to be infinitely high (Sammarco, 1991).

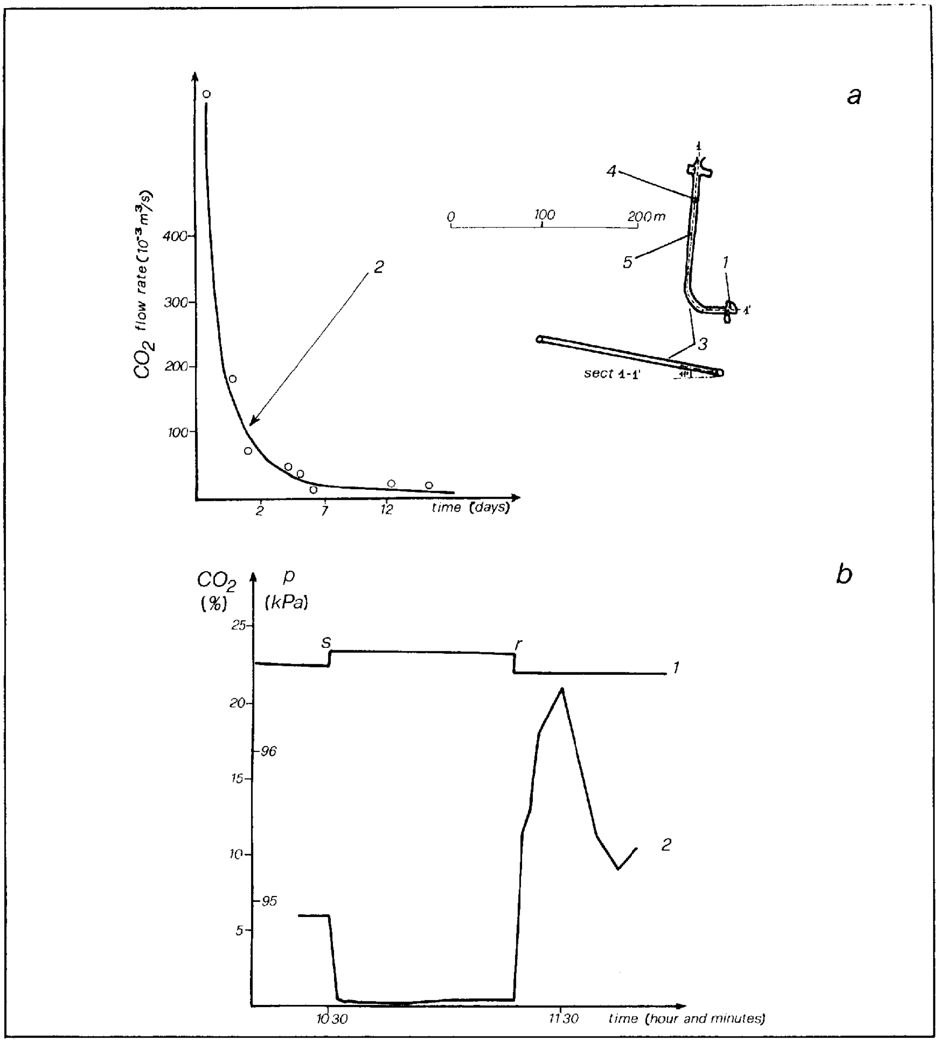

Figure 1 (a) CO_2 inrush into the Boccheggiano mine

1 - Inrush zone; 2 – CO_2 flow rate in the ramp after the inrush; 3 – Part of ramp invaded by gas; 4 – Blowing auxiliary fan; 5 – Pipe

(b) Influence of the atmospheric pressure on a CO_2 immission into an old gallery of the Selvena Mine.

1 – atmospheric pressure variations in the gallery for the stopping, s, and for the starting, r, of the fans; 2 – CO_2 concentrations in the gallery.

4 INTERACTIONS

4.1 Direct and indirect influence of water on the gas: factors controlling gas emissions

Water circulation, the changes and perturbations typical of water bodies and of circulating waters can influence gas emissions in various ways. The most significant ones are described below:

- If the gas that rises to the surface from underground or that flows into a mine gallery is above a water body, the rise of the piezometric surface causes the compression of the gas which in turn intensifies pre-existing emissions, may cause new emissions and occasionally explosions of the overburden where the latter has insufficient resistance. The lowering causes the expansion of the gas and hence a weakening of the emissions at the surface, and at times their total disappearance. Exceptionally that may not occur, for instance when the piezometric surface quickly drops, at a considerable amount of time after the rise of this surface, the amount of air aspired through the permeable surface formation can be so large that upon its subsequent swelling the gas emissions would have lower flows than those recorded at the previous lowering phase (Sammarco, 1981).
- As a result of erosion, transportation, deposition, dissolution and precipitation processes, the circulating waters continuously change the permeability of the formations they cross. If such formations were also to be sites of gas downflows the permeability variations would manifest themselves not only as springs flow variations but also as variations in the intensity of gas emissions. Following a period of intense and prolonged rainfall that caused the flooding of an underground mine subject to gas inflows (consisting mainly of CO_2), the permeability of the formations surrounding the mine increased so much as to allow the inflow of gas into the mine with flows that were three times higher than those prior to the flooding (Sammarco, 1999).
- The dissolution in water and the development of gas from the water are controlled by the physical and chemical characteristics of the water, and by atmospheric and rock features with which the water comes into contact. In particular, the interposition of a body of water between a gas emission and the atmosphere deeply changes the discharge mechanism notably because the water could accumulate gas up to saturation. In the case in which water were to be agitated, the accumulated gas develops in a manner that is more intense the greater the stirring of the water. This occurs because when the hydrostatic pressure on the masses of water that rise to the surface decreases as a result of the stirring, the sum of the partial pressures of the gases dissolved in those masses of water tends to prevail on the hydrostatic pressure; the greater and the longer such prevalence, the greater the amounts of the gases that are released and the intensity of their release.

- As the water circulates it can, according to the circumstances, transport, dissolve or release gas. Therefore for the gases water is a transportation system: when the water flows at the surface, the gases can be discharged into the atmosphere directly from the water, whereas when the water flows underground the gas will escape at given points along the water's path. Obviously if the paths change so will the points from which the gases rise to the surface.

All the factors mentioned above, that may all occur at the same time, are merely hydro-geological changes which, together with the geo-morphological changes, even those that are not induced by the presence of water, and anthropic changes, all have an impact on gas emissions and on sources. The effects produced by all these factors can be pointed out by comparing situations relative to different periods of time. Figure 2, which illustrates the 1965 situation of Mount Amiata and of its surrounding area, gives also the location of gas emissions and of warm mineral water springs detected in 1905, these are different not only in number but also in location with respect to those found in 1965 (Sammarco, 2000).

4.2 Influence of the gas on water

The gas that penetrates into or is present in the water may appreciably influence the chemistry and the static and dynamic conditions of the water. Some of these actions are analysed:

- Let us suppose that the gas consists mainly of CO_2. The release of carbon dioxide from the water may, among other things, bring about the precipitation of $CaCO_3$ along the conduits of the formations crossed by the water hence reducing the permeability of such formations. Vice versa, the dissolving of CO_2 in water may cause the dissolution of the $CaCO_3$ along the paths of the water hence increasing the permeability of the formations.
- The expansion of the gas as it rises to the surface acts on the water, that it is mixed with or that it encounters or attracts as a result of its outflow, making it rise. The water may reach the surface if the expansion energy is sufficient for having the water rises to the surface together with the gas, overcoming friction. Mention can be made here of the continuous and intermittent natural jets of water and gas, the extraction of mineral water obtained by making the gas, issued or contained in the water, expand sufficiently and likewise the geysers where the water rises to the surface by exploiting the expansion energy of the steam which is produced intermittently whenever the water temperature reaches boiling point at the pressure exercised by the overlying water column.

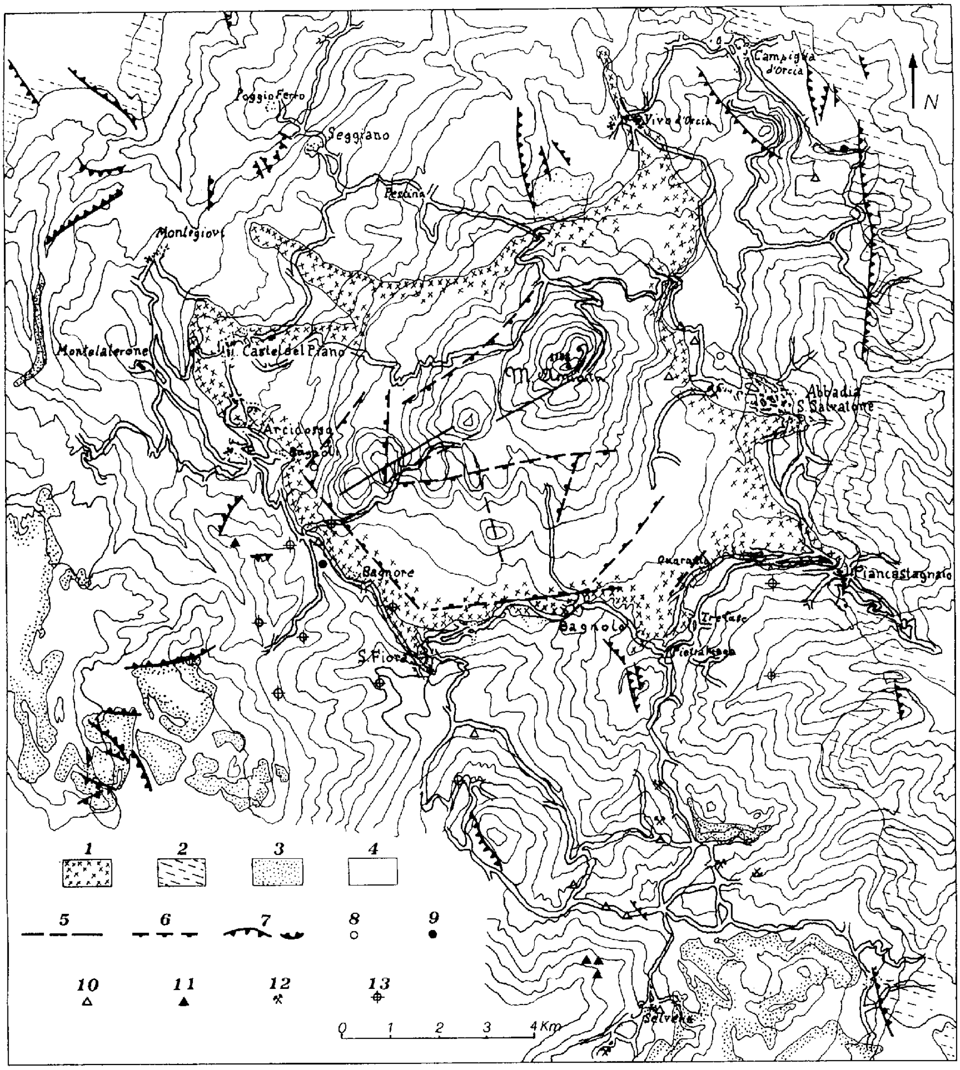

Figure 2 Sulphureous exhalations displacements in the zone of the Monte Amiata Volcano, Tuscany, Italy: Outcrops, mines, geothermal wells, water and gas emissions.
1- Igneous Complex: Ignimbrites, Trachites (Plioc. – Pleist.); 2 – Neoautochthonous Complex: Marine (L. Plioc.) and Lacustrine U. Mioc) Formation; 3 – Allochthonous Complex: Clays, Sands, Sandstones, Shales (L. Cret. – U. Cret.); 4 – Lower Complex: Limestones, Marls (U. Trias); 5 – Eruption faults; 6 – Volcano - tectonic faults; 7 – Normal faults; 8 – Thermal and mineral springs on the 1905; 9 – Thermal and mineral springs on the 1965; 10 – Sulphoureous exalations on the 1905; 11 – Sulphureous exalations on the 1965; 12 – Mines; 13 – Geothermal wells.

5 EXPLOITATION OF THE CARBON DIOXIDE AND MINERAL WATER: DETERMINING THE INFLUENCING FACTORS

The gas is released from an over-saturated solution forming swarms of bubbles that attract other gas as they rise. If degassing is intense the swarms make the surrounding masses of water rise as well in appreciable amounts; the more intense the degassing, the higher up goes the water and in greater amounts. Consequently, if the water body is superficial, its surface will be more agitated the greater the flow and expansion of the gas which develops. If it is a permeable formation containing water and gas, the rise of the gas/water mixture through a well connecting the formation to the surface will be controlled by the gas flow and by the expansion of the gas along the well, which in turn are controlled by the pressure difference between the pressure in the mixture inside the formation and the pressure at the head of the well during operation: by increasing such difference the gas flow rate and expansion increase and consequently so does the motor power available to bring the mixture to the surface.

This system is used to exploit the S. Albino (Tuscany) carbon dioxide and mineral water deposit. At first only the carbon dioxide is extracted by capturing it at the surface emissions, without acting on the pressure in the points of issue. The overall flow of these emissions, which has remained constant ever since it started to be measured, that is to say for over 70 years, is 1.9N/s. Later with the drilling of wells, carbon dioxide and mineral water were found in the Jurassic limestones and in the immediately overlying sandy and/or gravelly layers at depths between 100 and 160 m and an initial pressure between 1.1 and 1.3 MPa.

In order to understand which parameters have the greatest influence on the extraction of the water and gas from this field, significant data measured in some wells have been taken into account, namely when the wells were closed, when only CO_2 flowed and when both CO_2 and mineral water flowed from them. By using such data it was possible to find out the following:

- How frictional resistance varies in time by using the energy conservation relationship;
- By relating events and changes in conditions, the most likely causes that may have influenced the dynamics of the gas and of the water.

Well n° 2 was taken into account most of all. When well n° 2 entered production there were from the well only CO_2 emission if the pressure immediately upstream from the valve at the head of the tubing was above 686.70 kPa, and CO_2 plus mineral water if the pressure was lower than this value.

Supposing that the formation crossed by the fluid that reaches the base of the tubing is a conduit in series with the tubing, and supposing that the fluid is subjected only to the force of gravity and is in permanent motion, the equation of the motion can approximately be expressed as:

$$-vdp = d\left(\frac{u^2}{2g}\right) + dh + dR \qquad (2)$$

Or as:

$$-\int_{p_1}^{p_2} vdp = \frac{u_2^2 - u_1^2}{2g} + h_2 - h_1 + R_{1-2} \tag{3}$$

where

v = specific volume of the fluid, in m^3/N,
p_1 = pressure at station 1, in N/m^2 ,
p_2 = pressure at station 2, immediately upstream from the valve through which the pressure at the head of the tubing is regulated, in N/m^2,
p = pressure between station 1 and station 2, in N/m^2 ,
g = gravitational constant, in m/s^2 ,
u_1 = fluid velocity at station 1, in m/s,
u_2 = fluid velocity at station 2, in m/s,
h_1 = height of station 1 , bottom of the tubing, in m,
h_2 = height of station 2, top of the tubing, in m,
R_{1-2} = work done against friction for 1N of fluid between station 1 and station 2, in m.

Let us suppose that the fluid expansion from p_1 to p_2 is isothermal, then

$$-\int_{p_1}^{p_2} vdp = \int_{v_1}^{v_2} pdv = RT \ln\frac{p_1}{p_2} \tag{4}$$

where

v_1 = specific volume of the fluid at station 1, in m^3/N,
v_2 = specific volume of the fluid at station 2, in m^3/N,
T = temperature of the fluid, in K.

Supposing that station 1 is in the formation and sufficiently distant from the base of the tubing, it can be considered p_1 to be equivalent to the static pressure and $u_1 = 0$.

With this assumption, rel. (3) says that the isothermal expansion energy of 1N of gas makes it rise from h_1 to h_2 and flow, at station 2, at the speed u_2 doing work, for N, against friction of R_{1-2}

In terms of power, the following relationship can be written:

$$q_{g,w} RT \ln\frac{p_1}{p_2} = q_{g,w}\frac{u_2^2}{2g} + q_{g,w}\left(h_2 - h_1\right) + q_{g,w}R_{1-2} \tag{5}$$

where

$q_{g,w}$ = gas flow in weight, in N/s
$q_{g,w}\ R_{1-2}$ = power used to overcome the friction between station 1 and station 2:
P_R, for $q_{2g,w}$ N/s of gas, in *W*.

To examine how this quantity varies in time, successive periods have been taken into account during which, by adjusting the valve immediately downstream from Station 2, it was possible to have only CO_2 outflow at constant flow. Having set $h_2 - h_1 = 130$ m, since the productive layer which is assumed to be horizontal lies at that very depth, the cross-section of the gas flow equal to 0.031 m^2, since this is the cross-section of the tubing at station 2), and having set $T = 285$ K, and having measured the static pressure, the pressure at Station 2, and the gas flow, kept constant varying the latter pressure constant, for each period the value of P_r was inferred. The results are shown in Table 1.

Table 1 Friction Power

Years	Static pressure p_1[kPa]	Pressure at station 2 p_2[kPa]	Gas flow rate $q_{g,w,}$ [N/s]	Friction power P_R[W]
1967	882.90	686.70	2.452	2854.91
1970	882.90	676.89	2.452	3048.16
1972	882.90	647.46	2.452	3647.36
1973	882.90	627.84	2.452	4061.63

Table 1 shows how the power absorbed to overcome friction increases with time. From 1967 to 1973 it increased by 40% over the initial value measured in 1967. Such increases may have occurred above all because during the periods when the gas was extracted together with the water, the water would release CO_2, as the pressure would decrease along the paths followed by both fluids, and $CaCO_3$ would precipitate and obstruct the paths.

Figure 3a shows as a function of time the water flow-rate that could be extracted from three wells, namely well n° 2, well n° 3 and well n° 11, through the discharge from each of them of carbon dioxide with flows of respectively 3.54, 0.81 and 4.32 N/s. It can be noticed that there was a decrease in time in the flows from wells 2 and 3: before the entry into operation of well n° 3, the flow of well n° 2 dropped by 40% with respect to its initial value. Such reduction can be seen also in Figure 3b, which reports, as a function of the cumulative production of the well n° 2 CO_2, the water flow-rate for well n° 2 at the time when 3.54 N/s of gas were extracted from it. A possible explanation is that the increases in expansion power of the gas, produced in order to maintain the CO_2 flow constant, were lower than the increases required to overcome the friction which would have been encountered maintaing water flow-rate costant. One cannot rule out, however, that the decreases in water flow may have been caused also by a lowering of the water "level" inside the formation.

Figure 3a shows appreciable reductions in the flow of extracted water, occurred for well n° 2 in consequence of the entry into operation of wells n° 3 and n° 11, located respectively at some 670 m NW of well n° 2 and at some 580 m SE; and for well n° 3 as a result of the entry into operation of well n° 11 located at 960 m SSE of well n° 3. This because the extraction from the other wells brought about drops in pressure in the wells in operation that were not offset in order to water production, by prompting reductions in the pressure at the head of the tubings so as to keep the CO_2 flow constant.

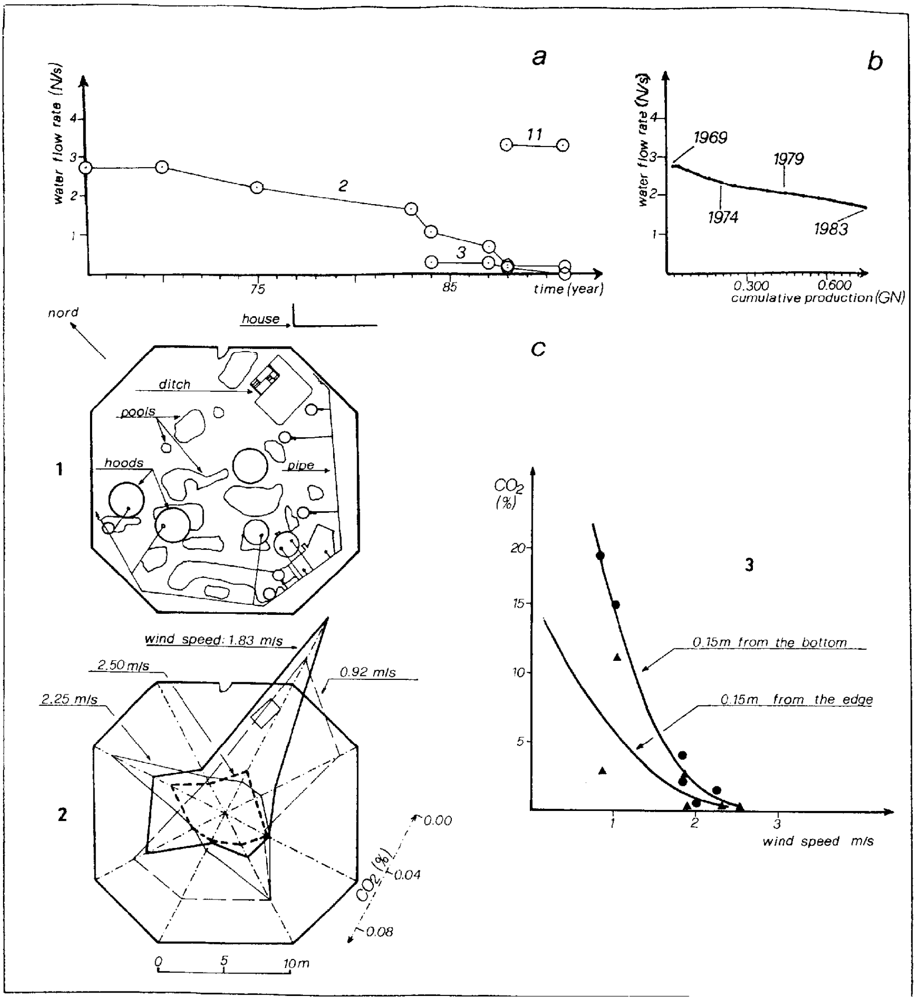

Figure 3 S. Albino field. Water flow rate that could be extracted from the wells 2, 3 and 11, through the emission from each of them of CO_2 with flows of respectively 3.54, 0.81 and 4.32 N/s versus time (a) Water flow rate extracted from well 2 together with 3.54 N/s of CO_2, versus cumulative production of CO_2 of the same well (b) .
1 – Octagon inside which there are gas emissions with overall flow rate constant; 2 – CO_2 concentrations in the air at the vertex of the octagon for different wind speed ; 3 – CO_2 concentration, at 0.15 m from the bottom and from the edge of the ditch, versus wind speed (c) .

It was also found that the pressure in each well after its closing down would go back to the value of the initial static pressure at a rate that was slower the greater the intensity and the duration of the delivery of gas and water. Upon reopening the well the gas and water would be delivered once again unless it had not been possible to lift the water to the surface before closing the well. This is due to that fact that by increasing the cumulative production of both gas and water, the extent of the depressurised zone around the well increases: in other cases it has been found that the delivery of gas from wells drilled ad hoc, would lead to an attenuation of gas emissions into the nearby mines and the disappearance of gas emissions at the surface.

From these results there ensues that

- If the production of CO_2 from a given well is to be kept in time, then the production of water should be limited so as to avoid excessive increases of friction that could also prevent the gas from flowing;
- If the production of mineral water is to be secured or if excessive expansion power consumption is to be avoided, then either an additional well needs to be drilled if the water flow reductions were to depend on increases in friction, or the production of water needs to be reduced or discontinues until the pre-existing levels are restored, in the case in which the flow reductions were to depend on a lowering of the underground water level ;
- In circumstances requiring special care, in order to ensure continuous water and/or gas production, the natural dynamics of underground fluids must not be disturbed, by collecting the fluids at the points of spontaneous emission without raising the flows above the natural flows.

6 CONCLUSIONS

The analyses made of the behaviour of a mineral water and CO_2 gas field in different stages of extraction and at the time of significant events, have made it was possible to infer some fundamental criteria useful for optimising exploitation.

There are always risks linked to the presence of CO_2 and of other gases not only in the zones where CO_2 is exploited but in any area where there are gas emissions where CO_2 is the predominant gas, whatever the ways in which the gas is issued into the atmosphere.

Such risks depend on the concentration of CO_2 and of other toxic and harmful gases, that may be mixed with the CO_2, when they are discharged at the surface or into the ventilation air in underground mines. And the concentration of such gases depends in turn on the factors that influence their emission into and on those that control their diffusion in atmosphere. Such latter factors are the specific weight of gas with respect to the air, the morphology of the area of emission and the weather conditions, in particular the winds. Figure 3c shows how the speed and of the predominant wind influence the CO_2 distribution in the air, and how the hight specific weight of such gas, equal to 1.5 that of the air and insufficient ventilation facilitate the accumulations of CO_2. This figure refers to the mentioned S. Albino field: in the upper left an octagon is traced inside which gas, composed mainly by CO_2, flows with constant overall flow-rate; in the lower left the CO_2 concentrations in the air at the vertexes of the octagon and for different ventilation conditions are shown; on the right the trends are shown, as a function of wind speed, of the CO_2 concentrations at 0.15 m from the edge and 0.15 m from the bottom of a 1.30 m deep ditch located inside the octagon (Sammarco & De Col 1981).

The risks could be eliminated or at least reduced by either taking measures to prevent damage for possible gas immissions into atmosphere or by preventing the issuing of gases into the air. In the former case, the zones that are either close to potential gas emissions or for their morphology and weather conditions can be exposed to gas concentrations above safety limits, need to be delimited and access to such zones prohibited. In the latter case, the gas bearing formations need to be drained of the gas they contain so as to reduce their pressure, and if steam is present this too needs to be removed, exploiting where possible the energy contained in such fluids (Sammarco, 1996). To demonstrate that it is worthwhile testing out this latter alternative it is sufficient to compare the amount of gas that was violently emitted by Lake Nyos, estimated to be around 10^9 m^3 (Tazieff, 1989), equivalent to less than 2×10^6 t, with the average annual production of the geothermal fields of Southern Tuscany between 1970 and 1995. Which was between 1.5×10^6 and 3.3×10^6 t/year and on average greater than 2×10^6 t/year of high enthalpy geothermal fluid.

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Emisja wody i gazu: dynamika i oddziaływanie wzajemne

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Streszczenie: Artykuł dotyczy wydobywania się na powierzchnię, w obszarach wulkanicznych, wód mineralnych i/lub gazów składających się głównie z CO_2. Badane są mechanizmy i czyniki powodujące i kontrolujące wznoszenie się wspomnianych mediów ku powierzchni ze szczególnym uwzględnieniem wzajemnego oddziaływania woda – gaz. Omawiany jest przypadek wypływu wody mineralnej ze studni jako wyniku ekspansji gazu obecnego w wodzie. W pracy proponowane są terenowe metody optymalizacji eksploatacji wód mineralnych i CO_2.

Rozważano również czyniki kontrolujące dyfuzję gazu oraz zagrożenia związane z jego akumulacją w obszarach zarówno eksploatacji jak i naturalnej migracji na powierzchnię. W pracy przedstawiono metody zabezpieczające przed niebezpieczeństwem związanym z niekontrolowaną migracją gazu poprzez eksploatację zgazowanych wód i obniżenie ciśnienia gazów.