Exposure of Workers to Electromagnetic Fields (EMF) Inside the Olive Mills: Preliminary Evaluations During the Oil Production [1]

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Abstract
In this note the experimental results of an analysis of the electromagnetic fields present in the productive area of new built oil-mill, placed in Bari district, considered representative of the majority of such a kind of the workshops in the Apulia region, are reported. Introductory study's purpose has been evidently to evaluate the exposure level of the workers during an oil production activity, inside a typology of transformation systems much spread on the Apulian territory that, even though with seasonal character, gives occupation to a big number of operators.
Results of the tests highlight that inside the considered oil-mill there are not electromagnetic pollution risks for the operators during the period of maximum use of its productive capacities.

Keyword: electromagnetic fields, olive mills, risk analyses, worker health

Introduction
The riskiness connected to the diffusion in the environment of the electromagnetic fields (EMF) has emerged in the last decades as their use has got always more intense in the civil applications; it's useful to remember that most technological applications use alternating tensions and currents that, therefore, produce alternate electrical and magnetic fields (Bevitori, 2007).
Under the sanitary point of view, in fact, an individual dipped in an electromagnetic field interacts with it creating a physical coupling between his biological system and the field, which evidently produce a deviation from the conditions of electrical balance at molecular level (Chatteron *et al.*, 1992).
The field frequency and the dielectric features of biological tissues affect the physical mechanisms of coupling between electromagnetic fields and biological organisms, therefore the maximum limits are expressed as a function of the frequency (Widermann *et al.*, 2005).
Within the low frequency electromagnetic fields (0 ÷ 10 kHz), a person's exposure is directly bound to the values of a few electrical characteristics which establish themselves as an effect of such fields, inside the human body: such characteristics, internal or primary, are essentially the *intensity of the electrical field* and above all the *internal current density*, defined as the current which passes through a unitary section perpendicular to its direction in a conductive volume such as the human body or a part of it (Rubin *et al.*, 2005).
These characteristics are of difficult measurement in the real exposure conditions and therefore, the check of the exposure of a person to the electrical and magnetic fields is led measuring the so-called outside or derived characteristics, that is the effective values of the inductive electrical and magnetic fields in absence of the exposed body. After evaluated the

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exposure conditions and the relative characteristic of the electromagnetic field, by mean of dosimetric models from the derived characteristics are evaluated the primary ones (D'Amore, 2003).
The Italian law in force regarding the workers' safety (Italian law decree and subsequent supplements n. 81, 2008) also counts among the various risks for the health of the workers the ones connected to the exposure to electromagnetic fields (0 Hz ÷ 300 GHz) during the job. These regulations regard the protection from the risks for the health and the workers' safety due to the well-known short term harmful effects in the human body deriving from the induced current circulation and energy absorption and from contact currents. In the law decree 81/2008 are defined: a) the limit values of exposure to the electromagnetic fields, based directly on verified effects on the health and on biological considerations, whose respect ensures the protection against all the well-known short term harmful effects for the health; b) the action values, directly measurable and whose observance assures the respect of the pertaining limit values of exposure, which determines the obligation to adopt one or more of the specified protection strategies.
In the agro industrial sector generally and in the olive oil production sector, with special reference to the manufacturing that happen in the oil-mills, the prevailing electromagnetic fields are the one at extremely low frequency (ELF, 30 ÷ 300 Hz), because they are due to the presence of electrical distribution lines and electrical motors working both at the 50 Hz industrial frequency.
In this note the experimental results of an analysis of the electromagnetic fields present in the productive area of new built oil-mill, placed in Bari district, considered representative of the majority of such a kind of the workshops in the Apulia region, are reported.
Introductory study's purpose has been evidently to evaluate the exposure level of the workers during an oil production activity, inside a typology of transformation systems much spread on the Apulian territory in relation to electromagnetic fields generated by the machineries used for the extractive purposes.

Materials and methods

The considered oil-mill, located in Corato (BA) countryside, has a typical lay-out of many productive realities of the northern Apulia, as they integrate deferring continuous cycle productive lines are present, in fact, 2 lines with stone mill (line 1 and line 2) and 1 line with metal crusher (line 3) (Figure 1).
Under the organization point of view, the oil-mill is family driven and during the oil production period, the oil-mill works 24 hours a day; in such conditions, the workers follow the production in 8 hours turns each.
The evaluation of the level of exposure to the electromagnetic fields has carried out first of all analysing both the spatial arrangement of the electrical machines inside the oil-mill, and the relative working cycles taking care to the workers individuals' duties, with their recurring working paths and the standing points.
Referring to what above reported during the extractive activity and during each working turn, with 3 operative lines simultaneously used, the working cycles of the various machines are not very different in terms of use, in terms of special arrangement of the utensils, in terms of electrical current absorptions and in terms of workers' operations and paths.
On the basis of this checking, it has established to carry out just one explorative measurement or "spot" of the field in 15 point at the working area: near electrical engines used by the operating machineries (stone mill, malaxer machines, decanter, vertical centrifuges) of the 3 above-mentioned extractive lines and near general electrical panelboard (Figure 1), with the

aim of evaluating the trend of the electromagnetic field and identify any critical points at higher intensity level on which investigate, later, with measurements sampled for all the duration of the working turn.

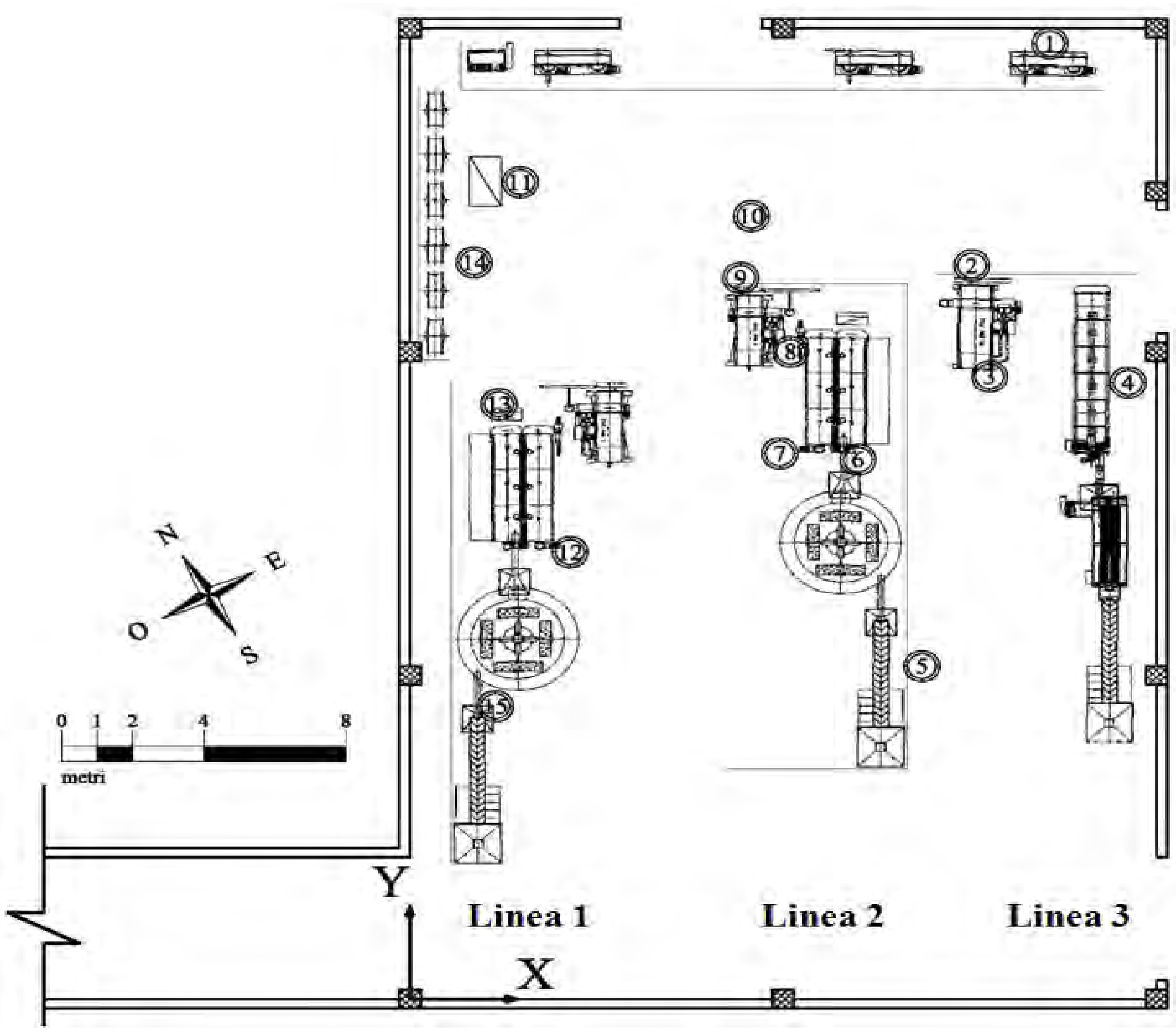

Figure 1. Studied oil-mill lay-out with indication of electromagnetic field measurement points.

Referring to extraction line 3 (Figure 1) the measurement points were: 1-back side of vertical centrifuge; 2-near decanter out; 3-near decanter in; 4-near malaxer machine out.
Referring to extraction line 2 (Figure 1) the measurement points were: 5-near leaf remover out; 6-near right side of malaxer machine in; 7- near left side of malaxer machine in; 8-between malaxer machine out and decanter in; 9-decanter side; 10-decanter out.
Referring to general electrical panelboard (Figure 1): 11-in front of it.
Referring to extraction line 1 (Figure 1): 12-near malaxer machine in; 13- near malaxer machine out; 14-near decanter out; 15-near leaf remover out
Measurements have been executed in all the points at a constant height by the floor of 1.50 m, which corresponds to the mean height of workers' thorax, and at a mean distance from each machinery of about 0.50 m.

Furthermore with this type of investigation it has been gathered information regarding to the frequency of the biggest spectrum line and the field distribution spectrum.
The evaluation of the electromagnetic fields has been executed on the basis of the Italian technical regulation in force (CEI 211-6, 2001); it's also useful to remember that the measure of low frequency electrical and magnetic fields has to be carried out in the so-called area of reactive near field, that's to say at distances from the sources lower than the λ wave length that, in the considered case of 50 Hz industrial frequency, is 6000 km.
As it is well known, in the reactive near field area no correlation between electrical and magnetic field exists: the first depends on the tensions present in the system or in the equipment which produces such fields, the second depends on the currents in them circulating, being tensions and currents completely independent. Therefore the complete characterization expects in any case the measure of both components: electrical field and magnetic field.
The system of measure of electrical and magnetic fields for low frequency used for the tests, was formed by an analyser PMM mod. EHP-50C, standing on a tripod mod. TR-02A, and from the gauge PMM mod. 8053A.
This instrumentation, in compliance with Italian Ministerial Decree 381 of 10/09/1998 and with Italian DPCM 08/7/2003 and whose main technical features are summarized in Table 1, it's extremely versatile and allows many measurement possibility with continuous monitoring also of many days.

Table 1. Main technical specification of the adopted instrumentation

	Electric field	Magnetic field
Frequency range	5 Hz – 100 kHz	
Level range	0.01 V/m -100 kV/m	1 nT – 10 nT
Overload	200 kV/m @ 50 Hz	20 T @ 50 Hz
Dynamic	>140 dB	

For each of the above mentioned measure points has been detected the orthogonal components x,y,z of the electrical and magnetic field for the 5÷100 Hz frequency spectrum, with a scan of 0.25 Hz,.
Figure 2, shows the position of the measure instrumentation near the leaf remover out (1 in Figure 2) and near the malaxer machine in (2 in Figure 2) that are both part of the extractive line 2.

Results and discussion
In Figure 3 are reported the effective values of electrical field E_{RMS} in each measurement point, obtained considering the components along the axies and the whole examined 5 ÷ 100 Hz frequency spectrum. In particular the value of electrical field at the generic E_i frequency is evaluated by mean of the following relation:

$$E_i = \sqrt{\left(E_{xi}^2 + E_{yi}^2 + E_{zi}^2\right)}$$

where E_{xi}, E_{yi}, E_{zi} are the components in the three x, y, z directions; the effective value of the electrical field E_{RMS} considering all the frequencies measured by the measurement instrumentation in the 5-100 Hz range in given by:

$$E_{RMS} = \sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n} E_i^2}$$

All the E_{RMS} values are considerably lower than the action values reported in the actual job safety laws and graphically reported in Figure 4, which determine the obligation to adopt one or more of the specified protection strategies.

Figure 2. Measure instrumentation positioning at leaf remover out (1) and at malaxer machine in (2).

Peak values of electrical filed E_{peak} obtained in the various measurement points have been all obtained at of the frequency of 50Hz and have been in any case lower than the correspondents effective values E_{RMS}; it's useful to remember that the electrical field is function of the tension, assumed to be constant inside the oil-mill, as the lighting equipment was fed with a single-phase tension (220 V) and the engines of the operator machines were fed with three-phase tension (380 V) or single-phase tension (220V).

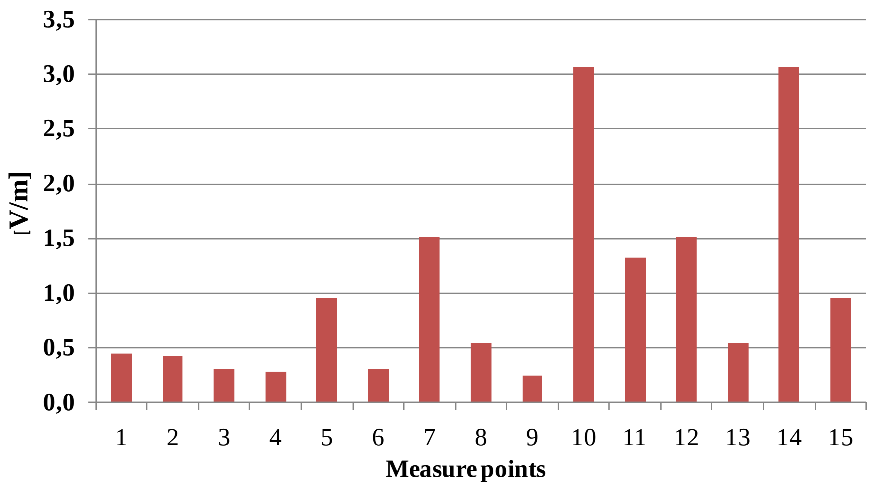

Figure 3. Effective values of electrical field E_{RMS} obtained in each measurement point

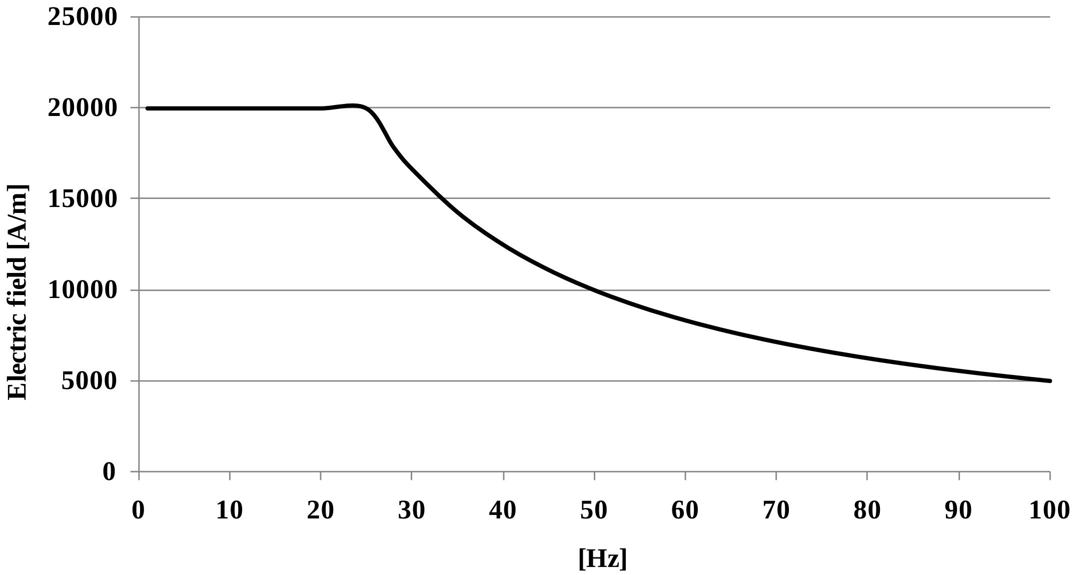

Figure 4. Effective action values of electrical field E_{RMS}.

In Figure 5 are reported the effective values of magnetic induction field B_{RMS} (also called magnetic flux density) in each measurement point, obtained considering the components along the axies and the whole examined 5 ÷ 100 Hz frequency spectrum. In particular the value of magnetic induction field at the generic B_i frequency is evaluated by mean of the following relation:

$$B_i = \sqrt{\left(B_{xi}^2 + B_{yi}^2 + B_{zi}^2\right)}$$

where B_{xi}, B_{yi}, B_{zi} are the components in the three x, y, z directions; the effective value of the magnetic induction field B_{RMS} considering all the frequencies measured by the measurement instrumentation in the 5-100 Hz range in given by:

$$B_{RMS} = \sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n} B_i^2}$$

All the B_{RMS} values are considerably lower than the action values reported in the actual job safety laws and graphically reported in Figure 6.

Peak values of magnetic induction filed B_{peak} obtained in the various measurement points have been in any case lower than the correspondents effective values B_{RMS}; it's useful to remember, besides, that the magnetic induction field is strictly related to the entity of circulating currents at the measurement instant. Having made the measurements in a period during which the oil-mill was in full activity and so with all the electrical users in a steady-state, it is plausible to think that these values are maximums ones to be considered in relation to the oil-mill full operation state.

It's important, otherwise, remember that, according to the theory of the multipole development, the trend of the magnetic field decreases in a hyperbolic way; therefore, at a distance from the machine of few meters, the magnetic induction field assumes values comparable with the underlying ones.

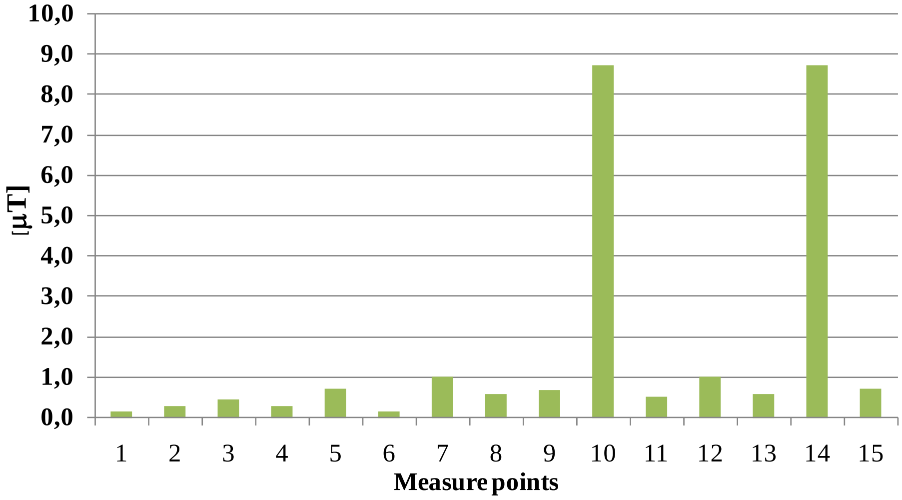

Figure 5. Effective values of magnetic induction field B_{RMS} obtained in each measurement point

Since have not been discovered critical points at high level of intensity both of electrical and magnetic induction field, next or higher than the correspondents action level, no further measurements sampled for all the duration of the working time were carried out.
This measurement typology would have been elaborated with statistical criteria (average, standard deviation, cumulative frequency curve, bends of frequency distribution etc), to highlight the field trend in the time and to provide an estimate both of the exposure levels and of the cumulative quantity in the time of development of the working activity or of the stay in the place of exposure to the field.
It would have been useful to execute also an explorative measurement campaign in the above-mentioned points with all or only some of the operator machines turned off so as to have a comparison with the underlying levels and verify, taking into consideration also the overlap effect, the contribution to the field distribution due by the single sources. However it was not possible to do that as the switching off of some or all the machines simultaneously would have interrupted the extractive production with repercussions on the quality of the final product.

Conclusions

Results of the carried out tests, also considering the limits of this introductory study, highlight that inside the analysed oil-mill, in the period of maximum use of its productive capacities, there are not risks for the operators bound to their exposure to electrical and magnetic low frequency fields.
It is useful to say that the electrical field only turns out significant if there are machines, conductors or, in general, users requiring high voltage; therefore, if equipments directly connected to mid or high voltage are excluded, particular interest arises the electrical field produced by the electroducts and, so, found in open field.
The magnetic induction field produced, instead, by most electrical users, with the exclusion of electroducts, has a low copulation with man and turns out in a close area around the source.

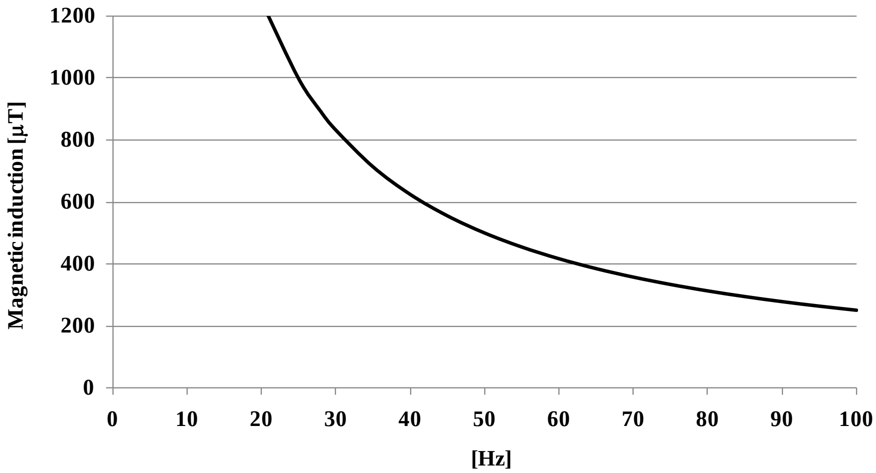

Figure 6. Effective action values of magnetic induction field B_{RMS}.

The investigation methodology tuned for this study, based on current Italian technical and legislative law indications is rather complex but can be used to make further studies regarding the electromagnetic field pollution in other agro-food sectors.

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