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Focus on coal power station installations and population health

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Summary. Damage to health associated with emissions from coal power stations can vary greatly from one location to another depending on the size of the plant, location and the characteristics of the population. Population-based studies conducted by independent groups in different locations around the world show effects on health in populations at higher risk, but failed to definitely demonstrate direct effects on morbidity and mortality, to be exclusively attributed to the presence of active power stations. However, evidence on the role of micropollutants from power station activities suggests that a complete and thorough analysis should be made on the environmental cycle. Therefore danger should in any case be assessed as carefully as possible while assuming, at most, that all micropollutants may come into direct contact with man through the various potential pathways throughout their entire lifetime, regardless of the factors that reduce their presence.

Key words: coal power plants, micropollutants, particulated matter, population health.

Riassunto *(Il punto su centrali termoelettriche a carbone e salute della popolazione)*. Il danno alla salute associato alle emissioni delle centrali a carbone può variare notevolmente da un sito all'altro, in funzione della dimensione della centrale, della sua localizzazione e delle caratteristiche della popolazione. Studi su base di popolazione condotti da gruppi indipendenti e in località diverse in tutto il mondo documentano l'esistenza di un impatto sanitario su popolazioni a maggior rischio, ma non hanno ancora confermato in modo definitivo l'esistenza di effetti diretti, in termini di morbosità e mortalità, attribuibili in modo esclusivo alla presenza di centrali attive. Tuttavia, l'evidenza sul ruolo dei microinquinanti derivanti dall'attività delle centrali impone la necessità di analisi complete e profonde sul ciclo ambientale. Pertanto, il rischio dovrebbe sempre essere valutato in dettaglio, assumendo che tutti i microinquinanti vengano a contatto diretto con l'uomo attraverso le diverse vie potenziali e per la loro intera permanenza nell'ambiente, e questo indipendentemente dai fattori che possono ridurre la loro presenza.

Parole chiave: centrali a carbone, microinquinanti, particolato, salute della popolazione.

INTRODUCTION

Increasing awareness on environment as a primary domain for health determines in wide sectors of public opinion concerns and civil petitions against the installation or transformation of energy production stations, with reference to emissions of potential environmental pollutants as determinants of disease in populations that reside in the concerned area.

The aim of this short report is to provide essential literature data about effects on the health of populations that surround a functioning thermal coal powered station.

HEALTH PROBLEMS WITH REFERENCE TO THE SPECIFIC POLLUTANTS RELEASED FROM COAL POWER STATIONS

The pollutants that are commonly associated with the activity of coal power stations are particulate matter (PM), ozone (O_3), sulphur dioxide (SO_2), nitrogen oxide (NO_x), carbon monoxide (CO), metals and volatile organic compounds (VOCs). As prescribed in 1990 by the American Congress Clean Air Act, the US EPA (United States Environmental Protection Agency) conducted studies that detailed the polluting emissions from electrical power stations [1]. The link that exists between single pollutants and adverse reactions on health, described in a report by the American Thoracic Society in 2000, has been depicted as a pyramid [2]. At its base are the most common consequences of exposure (increase in prevalence and incidence of respiratory diseases/symptoms and reduction in pulmonary function) and at the top is mortality, a less frequent yet much more serious consequence.

The pollutants associated with emissions from power stations have been linked to a variety of respiratory problems, including irritation of the airways, respiratory difficulty and a reduction in pulmonary function. In general, the effect of pollutants is more serious in individuals that already suffer from respiratory prob-

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lems such as asthma and chronic obstructive pulmonary disease (COPD), cardiovascular problems, and amongst the elderly and children. Exposure to pollutants can lead to an increase in episodes of hospitalisation due to respiratory disorders in individuals belonging to these groups [3].

Inhalation of PM is a major exposure at risk. PM is made up of a mixture of solid and liquid particles suspended in the airway. Two types of PM are associated with coal combustion. The primary PM is released directly into the air during combustion processes, whereas the secondary PM is formed through complex reactions between gas emissions (SO_2 and NO_x) and atmospheric irradiation. PM is also classified by size. Particles of a diameter of > 2.5 μm are defined as coarse PM and include dusts, pollens and spores. Following inhalation, coarse particles > 10 μm are generally deposited in the upper respiratory tract and removed. Coarse particulate between 2.5 and 10 μm can penetrate the thoracic cavity and lead to adverse effects on health. Fine particulate or PM 2.5 is the compound of residual ash resulting from combustion processes and from nitrates, sulphates and their aerosol acids formed by post-combustion atmospheric reactions. Sulphates, which are formed by SO_2 being released into the atmosphere, make up the largest component of PM 2.5. Power stations produce approximately two thirds of the SO_2 released. Nowadays, new technology allows ultrafine aerosols from coal combustion in thermal power stations to be distinguished on a semi-quantitative level [4].

Epidemiologic studies have repeatedly shown the link that exists between the environmental concentration of PM 2.5 and an increase in morbidity and mortality [5-7]. PM 2.5 has been specifically linked to an increase in episodes of hospitalisation for asthma [8] and other respiratory illnesses. Nonetheless, several studies have provided evidence that the coarse fraction of PM 10 also has a great effect on the rate of hospitalisation for asthma, COPD and on admissions due to respiratory illnesses in general [9].

Another significant pollutant is ozone caused by coal combustion. Ozone, the main element in smog, is formed by the reaction of sunlight on NO_x and VOCs in the atmosphere. The levels of ozone are higher during hot, sunny afternoons, with stale air. Approximately half of all NO_x are produced by motor vehicles, whilst power stations are responsible for about 25% of the NO_x present in the air [10].

The effects of ozone on respiratory health have been observed in a significant number of investigations, including clinical, toxicological and epidemiologic studies. Short term exposure to ozone is associated with a reduction in pulmonary function and with respiratory symptoms such as nose and throat irritation, coughing, wheezing and shortness of breath. Long term exposure can cause permanent pulmonary damage. Subjects with previous pulmonary diseases such as asthma, COPD and bronchitis are more sensitive to the effects of the ozone, which is considered responsible for 10-20% of out-patient visits and hospital admissions in areas with high atmospheric pollution. As for other pollutants, in a study conducted on more than one million youngsters in Taiwan, exposures to high levels of CO present a risk of asthma that is increased twofold [11]. The same study also showed that asthma attacks increased as the concentrations of O_3, NO_x, PM and SO_2 increased. Nonetheless, it is often difficult to distinguish the role of each single pollutant, since most of the time exposure occurs simultaneously. Furthermore, the different scenarios determined by the mix of emissions, atmospheric conditions and environmental conditions (urbanisation, population density) can determine a great variability in the composition of the aerosols inhaled, with potential changes in the toxicity of the emissions already discovered in laboratory studies [12].

Although the link that exists between single pollutants and adverse reactions on health is well documented in literature, it is important to note that the human response to pollution occurs along a spectrum and, therefore, assessment of the impact on the population is much more complex than the individual assessment of each case.

EFFECTS ON HEALTH AT POPULATION SCALE

Literature on the risks to human health from single environmental micropollutants is particularly vast, but this paper aims specifically to document the potential evidence that exposure to power station emissions determine measurable effects on the health of the population in the area concerned.

Exposure pathway analysis takes on significant importance in environmental epidemiology. An exposure pathway is the best method to describe how an individual comes into contact with chemical substances from a source of environmental contamination, and consists in the definition of five different factors: a) source of contamination; b) means of transport of the contaminant into and through the environment; c) locations where the individuals and the population come into contact with the contaminant; d) the exposure pathway of the individual to the contaminant (*e.g.*: air, food); e) the existence of one or more individuals (receptive population) that have come into contact with the contaminant. The pathway is considered complete if all five factors are defined and interconnected, or if it is probable that they will be in the immediate future. It is considered to be potential only if some of the five factors are (or have been) defined or if some are lacking in detail. The presence of a complete exposure pathway does not necessarily imply that there will be, or have been, adverse effects on health. The exposure pathway analysis tool is a precise method and is particularly useful for the localized analysis of phenomena surrounding industrial structures. It is currently used in the so called "Health Consultations" of the

Agency for Toxic Substances and Disease Registry (ATSDR) of the US Department of Health and Human Services. A consultation based on the exposure pathway analysis has recently been made on the health effects of a coal power station in Torrey, New York [13]. This study showed that analysis of hospital discharges for respiratory disorders did not highlight any greater risks for the population resident in the area affected by the power station.

Damage to health associated with emissions from coal power stations can vary greatly from one location to another depending on the size of the plant, location and the characteristics of the population, although the varying degree of the different factors that contribute to the general picture has not been assessed sufficiently, formally or in detail. In a recent study, damages from the activity of 407 coal power stations in the USA were modelled (in quantitative terms on an economic basis), with focus on premature mortality from PM 2.5 fine particulate [14]. By linking a non-linear concentration-response function for mortality linked to PM 2.5, the model demonstrated that the variability of damage per ton of emissions is almost entirely explained by the exposure of the population per unit of emission (intake fraction), and is in turn linked to the atmospheric conditions and the size of the population at various distances from the power station. The variability of damage to health per kWh is strongly linked to the amount of SO_2 emissions, which is also closely linked to control technologies, the type of combustible used, atmospheric conditions and the size of the population at various distances from the power station. Similar results have been obtained by evaluating the health benefits from a standard reduction in pollution [15]. Ultimately, control strategies that consider the variability of damage between different plants can provide much more analytical and refined results than traditional studies.

It should also be noted that the availability of data resulting from ecological-geographical studies regarding the surroundings of electric power stations, in proportion to the number of observational studies cited in literature and given the limitations of the observational approach is not relevant. We should also consider that much of the data available refer, in any case, to power stations with a design that is obsolete when compared to the new management, running, treatment and surveillance techniques available today. The studies mentioned below account for the differences in the impact on health of new generation power stations.

One study claims that individual exposures to coal radionuclides close to the power station in Langerlo (Belgium) are lower by several orders of magnitude when compared to exposure from old coal power stations [16].

A study conducted for the new technology coal power station in Abodo (Spain) documents a model for reducing the impact on health as a consequence of filtration techniques [17].

A study conducted in Japan on the impact of all coal power stations active in the country [18] concluded that the adverse effects on health from the entire annual air dispersion of mercury (0.63 ton/year) can be considered quite low.

A well documented systemic project of monitoring and analysis on the state of the health of the population in the Ashkelon region (Israel), where a coal power station was activated, has been carried out since 1989. Authorisation for operating the power station was granted on the condition that a network system for monitoring the environment, health and agricultural and food production be set up around it. In particular, the health monitoring system foresaw the registration of every admission to the hospital and out-patient welfare system in the area. The final assessment of the study on environmental impact led to the conclusion that the levels of pollution in the air, in the area covered by the study, did not exceed those of the strict standards of air quality in Israel, with particular reference to the monthly and annual averages for the main micropollutants, and no significant association was found between the levels of micropollutants and respiratory diseases in children [19]. Furthermore, this information was confirmed by a similar wide ranging study on the infant population conducted in South East Asia [20].

On the other hand, a recent study conducted in Israel showed that exposure to air pollution appeared to have had the greatest effect on children with untreated chest symptoms. This phenomenon may be explained by the fact that this untreated symptomatic group might experience the most severe insult on their respiratory system as a result of exposure to ambient air pollution, which is reflected by a considerable reduction in their respiratory volumes [21].

However, a study on the analysis of the general mortality for districts in Israel identified low, medium and high risk areas; the district of Ashkelon, which is affected by the coal power station, is amongst the low risk areas [22]. This study highlights an aspect that is often overlooked in the rough-cut analysis of local phenomena: the possible increase in incidence and mortality for some disorders in the population must be verified in relation to temporal and geographical trends in the widest areas of reference.

Other reports focus their attention on the emission of micropollutants. In particular, the potential carcinogenicity of micropollutants and the long-term permanence of mercury (Hg) in the water cycle have been underlined as being more significant problems. However, an eco-toxicological study was published on the monitoring of concentrations of mercury in the area surrounding coal power stations. Its conclusions showed that the impact of power stations does not determine significant variations on the pre-existing concentrations of mercury in the waters, therefore limiting the supposed risks associated with emissions of mercury from power stations [23].

Recent documentation shows that the vanadium ion acts as an enzymatic cofactor in the hormonal metabolism of glucose, lipids and some tissues (bone tissue in particular): the International Agency for Research on Cancer (IARC) include vanadium in its list of possible carcinogenic agents. Whilst per os ingestion of excessive quantities of vanadium does not seem to have significant acute toxic effects, low serum concentrations of vanadium would seem to be associated with cardiovascular risk; moreover, toxicity via the respiratory tract due to environmental pollution is more significant.

Overall, evidence suggests that in the presence of active power stations, complete and thorough analysis should be made of the micropollutant environmental cycle, with the aim of identifying the factors that connect their dispersion into the environment with man's actual exposure to contamination through the various pathways.

Although it can be reasonably considered that the group of phenomena that contribute to this cycle decrease progressively, starting with the emissions falling back to the ground and man's exposure to various pollutants. Therefore their danger, should in any case, be assessed as carefully as possible while assuming, at most, that all micropollutants may come into direct contact with man and be ingested through the various potential pathways throughout their entire lifetime, regardless of the factors that reduce their presence. According to the US EPA standards, NOAEL values (No Observed Adverse Effect Level, *i.e.* the highest level of exposure at which no significant increases, either statistical or biological, in the frequency or severity of negative effects exist in the exposed population and the appropriate standard under consideration) should always be provided on the chronic condition of the non-carcinogenic effects of at least two orders of magnitude above the values that can be found in the fully functioning models in areas with installations of power stations with new technologies.

PROSPECTIVE INDICATIONS FROM NEW TECHNOLOGIES

With regard to coal powering, the activation of new power plants with innovative technology should provide, at least in theory, maximum containment and treatment of emissions from the production cycle in order to guarantee systematic environmental and health monitoring of the populations in the area concerned, with a long period of follow-up and the aim of guaranteeing a standard of maximum caution and protection.

Conflict of interest statement

MV and ST were charged as epidemiologic consultants in law trials brought by thirds against the main Italian energy producer and distributor (ENEL).

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