



Coal Power Station Installations and the Health of Populations: A Review of Evidence and State of the Art in Italy

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Abstract

The link that exists between single pollutants and adverse reactions to health has been depicted as a pyramid. 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. Although this link 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.

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 different factors that contribute to the general picture has not been assessed sufficiently, formally or in detail. Nevertheless, the review presented here leads to the conclusion that the population studies conducted by independent groups in different locations around the world have not been able to successfully demonstrate the direct effects in terms of the morbidity and mortality that can be unequivocally be attributed to the presence of active power stations. However, evidence on the role of micropollutants from power station activities suggest that a complete and thorough analysis should be made on the environmental cycle where there are active stations. This analysis should aim at identifying the factors that link their spreading into the environment to man's actual exposure to pollution through the various possible 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.

Introduction

The increasing awareness of the importance of the environment as a primary area for promoting and maintaining health determines, in more or less wide sectors of public opinion, the development of concerns and civil petitions against the installation or transformation of energy production stations, with reference to emissions of potential environmental pollutants that may determine the risk of disease in the populations that reside in the area concerned. Due not only to the proper attention that society attributes to health as an asset and inalienable right, but also to the organisational capacity that determines them, such petitions meet with wide consensus and diffusion, however, scientific evidence to support these theories on the existence of risks does not appear to be sufficiently documented.

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

Review

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 (PM), ozone (O₃), SO₂, 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 [3].

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 problems 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 [4].

One significant problem is inhalation of particulate (PM, particulated matter). 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 [5]. PM is also classified by size. Particles of a diameter of $>2.5 \mu\text{m}$ are defined as "coarse" PM and include dusts, pollens and spores. Following inhalation, coarse particles $>10 \mu\text{m}$ are generally deposited in the upper respiratory tract and removed. Coarse particulate between 2.5 and $10 \mu\text{m}$ 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 [6]. Sulphates, which are formed by SO_2 being released into the atmosphere, make up the largest component of PM 2.5 [7,8]. Power stations produce approximately two thirds of the SO_2 released [9]. Nowadays, new technology allows ultrafine aerosols from coal combustion in thermal power stations to be distinguished on a semi-quantitative level [10].

Epidemiologic studies have repeatedly shown the link that exists between the environmental concentration of PM 2.5 and an increase in morbidity and mortality [11-16]. PM 2.5 has been specifically linked to an increase in episodes of hospitalisation for asthma [17] 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 [18].

Another significant pollutant is the 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 [19].

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 [20]. 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 [21]. 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 individual 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 [22].

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 the population: methods and outline of literature data.

Literature on the risks to human health from single environmental micropollutants is particularly vast. However, this certainly is not the subject of this paper, which instead, aims to document the potential evidence that power station emissions determine measurable effects on the health of the population in

the area concerned. In other terms, the general toxicology of the main micropollutants is not in question, naturally this can be seen in more specific research notes, but here we will consider the ecological evidence of an increase in epidemiological indicators of frequency and of risk in the presence of power stations. From a methodological point of view, *Exposure Pathway Analysis* takes on significant importance in environmental epidemiology. An exposure pathway is the method by which 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 U.S. 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 [23]. 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 very 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 [24]. 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 SO₂ 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 [25].

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 the fact 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 that are available today.

In terms of the general analysis of mortality in regional areas that have a strong industrial presence, the EUROSTAT data published in the Health Statistics series is cited as one of the typical examples (Subject 3: populations and social conditions, the European Union Atlas of Mortality) [26]. This may also be of interest in reference to the data for the European region with the greatest industrialisation, the Ruhr Lander in the Federal Republic of Germany. This region, with a concentrated population of around 11.3 million inhabitants, is of specific interest due to the presence of several coal powered electricity producing stations, exceeding 2000 Mwe, two of which have been running for more than 20 years (Weisweiler 1973, Neurath 1974) and one for 15 years (Scholven 1979). General mortality and premature mortality (0-64 years) in both sexes, in the Ruhr area, present values that are not unlike those for the whole of Germany; mortality due to respiratory tract cancers report a risk

that is clearly lower in that area compared to other European areas. The same considerations are true for mortality due to chronic respiratory conditions in both sexes. Although we should give due consideration to the fact that the values represented are average regional values and seem to suggest the absence of local spikes in incidence (on a European scale). However the concentration of high power thermal power stations with old technology that have been running for decades, which are certainly not characterised by high quality control of emissions, could be the cause of such a relevant factor of environmental pressure, contrary to the provisions for new coal power stations. 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 [27].

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 [28]. Other model studies confirm these effects. For example, a probability assessment was conducted on the health risks of methyl mercury (MeHg) from local coal combustion [29] in a worst case scenario. The study used the incidence of neurological disorders (paraesthesia) and congenital neurological defects as impact results, the conclusions showed significant safety margins for both potential clinical outcomes.

A study conducted in Japan on the impact of all coal power stations active in the country [30] 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 [31]. 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. The follow up on the incidence of respiratory disease in cohorts of children of school age confirmed that the increase in asthma and respiratory diseases, also found in the study area, is ubiquitous in Israel and presents a temporal trend that is not linked to the installation of the power station, the activity of which is, therefore, plausibly alien to the phenomenon (Goren et al., 1997). 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 [32]. Another study did not find any significant association between the levels of micropollutants and respiratory diseases in children [33]. Furthermore, this information was confirmed by a similar wide ranging study on the infant population conducted in South East Asia [34].

Furthermore, 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 [35]. 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 [1, 36]. 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. A project conducted in Slovakia seems to show the existence of a risk of skin cancer (non-melanoma) linked to exposure to foodstuffs contaminated with arsenic near a power station [37]. However, the same authors underlined the several biases that give rise to the conclusions in the case-control study (observational). Other studies tend to minimise such effects [29]. Quite recently an eco-toxicological study was published on the monitoring of concentrations of mercury in the area surrounding coal power stations. The conclusions of this study showed that the impact of power stations does not determine significant variations on the pre-existing concentrations of mercury in the waters, therefore greatly limiting the supposed risks associated with emissions of mercury from power stations [38].

This evidence does not exclude, but even 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.

The evaluative study by the US EPA on the risks from HAP (hazardous air pollutants) emission from the use of orimulsion [39] is of particular importance. In particular, by analysing HAP emissions (in particular nickel) in relation to the traditional oil-burning power stations, the EPA underlines that the control technologies needed for the commercial start-up of orimulsion power stations prompt the reduction of emissions at different levels of lower orders of magnitude. This practically implies a zero rate of occurrence of the already quite modest estimation of the increase in the incidence of cancer. Naturally, the appropriately severe conservatism of the EPA safety criteria leads to the conclusion that there is a need to produce accurate risk estimations using longitudinal models.

Such criteria of maximum caution were also introduced in a model study on the environmental impact of a power station with new technology [40] in the river Po "delta" area. This report showed how the health risks from contamination of the land and dispersion into the air of a series of HAPs (IPA, dioxins, arsenic, chrome, mercury, manganese, nickel and vanadium) can be considered practically irrelevant from an epidemiological point of view, using the severe US EPA standards as reference amounts to identify the potential risk to human health. The results of the study concerning the health risks linked to the release of vanadium are particularly interesting.

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). Whilst a low concentration of vanadium would seem to be associated with a risk of cardiovascular diseases, an ingestion of excessive quantities of vanadium by mouth does not seem to have significant toxic effects, whilst toxicity via the

respiratory tract due to environmental pollution is more significant. It should be noted that the International Agency for Research on Cancer (IARC) does not currently include vanadium in its list of carcinogenic agents. To assess the risk to health, the US-EPA provides NOAEL values on the chronic condition of the non-carcinogenic effects (No Observed Adverse Effect Level, which is 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) 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.

Epidemiology of cancer in the areas surrounding coal power stations: Italian references

In recent years the epidemiology of several noteworthy cancers has undergone changes in relation to the changing exposure to risk factors, such as lung cancer and other smoke-related cancers. This is also due to the implementation of screening programmes or the wide-spread use of instruments for early diagnosis.

The first consideration to be made is that the epidemiological analysis of mortality and of incidence in an area can never be far removed from the general datum of a wider reference territory on which data can be standardised. Although this may seem to be simplified, the problem lies in verifying whether the measures of frequency of the event in consideration, and their trend over time, follow dissimilar models (statistically) in relation to the geographic area of reference.

This problem has clearly arisen in almost all the contexts where assessment is made of the impact on health in the areas where Italian thermal power stations operate, in particular for the Po River Delta, Civitavecchia and Brindisi. Where the first two areas are concerned, the indicators of mortality that are available for cause and municipality have provided evidence that does not allow conclusions to be drawn on the actual role of power stations in determining the risk of death due to specific cancer causes, and in particular lung cancer, as was feared in preliminary results [41-43].

Often, groups of local scientists or medical experts state that in many Italian sites the incidence of cancer is increasing specifically in the area around a power station and the fact that this increase in incidence appears, from the results of certified cancer registration, to be ubiquitous, is not taken into consideration. For example, in the case of lymphoma,

the analysis conducted by the AIRT (Association of Italian Cancer Registers), on data pooled by nine official Italian registers, documents the existence for the entire national territory of an average annual increase in the rate of incidence in both sexes (EAPC, *estimated annual percent change*: males +3.4%, females +3.5%) as well as a consistent increase in the mortality trend for non-Hodgkin's lymphoma [44].

The analysis mentioned above demonstrates that the rates of national incidence emphasise, in both sexes, a tendency to a statistically significant increase for all cancers. The average increase in rates was 1.1% a year in males and 1.5% a year in females. On the contrary, mortality rates due to cancer are dropping significantly.

As far as incidence in Italy is concerned, significant increases, presumably linked to a real increase, are present in lung (in females), colon, bladder, liver, pancreas, mesothelioma, Kaposi's sarcoma, testicle, non-Hodgkin's lymphoma and multiple myeloma cancers. In some locations the increase in incidence should be associated with the development of screening programmes (female breast screening), with activities of early diagnosis, increased diagnostic abilities and technological development. There is a reduction in the incidence for lung cancer - only amongst males as observed for other smoke-related sites (oral cavity, oesophagus, larynx) - as well as stomach cancer in both sexes, Hodgkin's disease amongst males and bile duct cancer in females.

When local trends are in line with national trends for incidence and mortality, it becomes difficult to attribute any health phenomena to typically local factors.

Numerous literature studies, although not pertinent to this analysis, look at the health risks in an industrial and professional context from coal processing and its by-products. It should be noted that such references are valid in a medical-legal context but have little relevance for the purposes of an environmental investigation.

Conclusion(s)

Ultimately, we are able to confirm that in light of scientific literature, the activation of new power plants with innovative technology can provide maximum containment and excellent 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.

This evidence does not exclude, but even 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 contribute to a progressive decrease, 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.

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