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Air and Leaching Pollution Scenario by Iron and Steel Plants, in central India

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ABSTRACT

Industrialization is essential to meet up upcoming demands of the evolution. All the industrial activity releases some amount of by-products as pollution into the environment. Iron and steel industry is one of the major heavy industries of Chhattisgarh and considered as resource intensive and pollution prone and added pollution to air, water resources, precious land. In central India many of the integrated iron and steel industry is *highly polluting, non-compliant and resource-inefficient.* The aim of the present review is to understand and get aware with the pollution, mainly (i) stack emission as air pollution, and (ii) heavy metal leaching from piled iron and steel slag, by steel plants in Chhattisgarh, central India region.

Introduction

The world crude steel production in the year 2014 reached 1661.5 million tonnes and shows an increase of 1.2% over 2013 steel manufacturing (WSA, 2016). World's largest crude steel producer in 2014 (823 MT) was the China and is followed by Japan (110.7 MT), the USA (88.3 MT) and India (83.2 MT) secured the fourth major crude steel manufacturing country of steel (http://steel.gov.in/overview.htm - accessed on 8 August 2016). In 2013-14, Indian steel production for sale of total finished steel consisting of alloy and non alloy was 87.67 MT and 65.197 MT respectively, during April-December 2014-15 (provisional) (Ministry of Steel, India, http://steel.gov.in/overview.htm - accessed on 02 July 2015).

In India, iron and steel industries are, among the 17 most polluting industrial sectors, identified by the Central Pollution Control Board (CPCB). Air emissions from Iron and steel industries is an important source of pollution (Liu et al., 2013; Rai et al., 2011), during all its processes —handling of raw materials, producing iron and steel or disposing of solid waste (downtoearth.org.in). The production of 1 tonne of iron requires 1.4 tonnes of raw iron ore materials; 0.5 to 0.65 tonnes of coke as fuel; 0.25 tonnes of limestone or dolomite; and 1.8 to 2 tonnes of air (https://www3.epa.gov/ttnchie1/ap42/ch12/final/c12s05.pdf - accessed on 5 August 2016) and resulted in 1.0 tonnes of iron, 0.6 tonnes of slag, 0.1 tonnes of flue dust and 5.1 tonnes of blast-furnace gas (Wesley and Hemeon, 1957). The recovery and use of steel industry by-products universally has contributed to a material effectiveness rate of 96% (World Steel, 2014). The main by-products produced during iron and crude steel manufacturing are slag (90% by mass), dust and sludge (WSA, 2016). Presently, Indian steel industries generate industrial solid waste, in the range of 450 - 550 kg/tonnes of crude steel production (http://www.meconlimited.co.in – accessed on 15 July 2016). The fundamental types of industrial pollution are air, land, soil, water, and noise pollution (http://www.mse.ac.in /ManagingEnvironment/discussion.pdf - accessed on 30 June 2015) and this sector also causes considerable effects of environmental medium – air, soil and water (http://www.eolss.net/sample-chapters/c09/e4-14-04-04.pdf - accessed on 07 August 2016).

The central India scenario

A pollution problem from iron and steel industries does not seem in Chhattisgarh, merely as particulate matter, but poses problems even for water sources too (Das, 2014). Raipur, Bilaspur, Korba and Durg-Bhilai Region are major industrial regions in the state (http://industries.cg.gov.in/Industrial_Regions.aspx - accessed on 05 August 2016). There are more than a hundred steel rolling mills, sponge iron plants and Ferro-alloy units all of which are efficient to supply world-class output and Bhilai, Urla, Korba, Raigarh, Durg, Siltara and Bilaspur are the major industrial regions as the steel hub of the state (Kesari and Verma, 2015). Raipur is one of the fasted growing and richest cities amongst major industrially developed cities and India's biggest iron market as in the district about two hundred steel rolling mills, five hundred agro-industries and more than forty seven sponge iron plants are located (http://cpcb.nic.in/SPMCharacterization.pdf - accessed on 15 July 2016). The industrial area Silatara in Raipur and Raigarh are a hub of sponge iron industries, and has witnessed most of the pollution load in ambient air (A – Report, CPCB, Bhopal, 2011). There are twenty four sponge iron plants, in and around Raigarh, producing approximately 12,360 TPD of sponge iron and M/s Jindal Steel and Power Limited (JSPL), world's

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leading sponge iron, in addition to steel plant is too located nearby (http://cpcb.nic.in/SPMCharacterization.pdf - accessed on 15 July 2016). The Bhilai steel plant generates around 2.1 million tonnes of slag every year, of which 81 per cent is blast furnace air-cooled and granulated slag (DTE – 1). This review paper discusses the impacts of emission and slag pollutions on air, water and soil by the iron and steel industry in the study area.

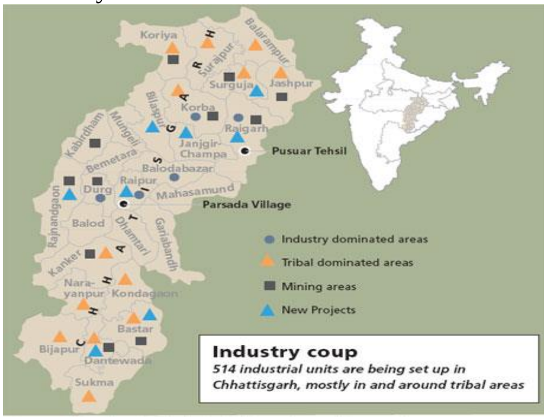

Figure 1. Major Industrial Regions of Chhattisgarh (CSIDC).

Iron and steel industry pollution

Steel and iron production is a part of rapid development, has annoyed ecological problems with a huge amount of wastes and its management consequences (Viswanathan and Gangadharan, 1996). The iron and steel industries are the highest in energy and natural resources consumption, leads to huge amounts of air pollutants such as SO_2, NO_x, PM, VOC, and PCDD/Fs and thus resulting in considerable local and worldwide environmental problems (http://eprints.nmlindia.org/4219/1/168-181-_A_K_Vaish.PDF - accessed on 10 August 2016; Wu et al., 2015). Concern of steel sector in the direction of air and water pollution was noticeably high, and their present methods of solid waste management scenario are abysmally poor (downtoearth.org.in). Also, for every tonne of steel production, on an average, the industry has dumped half a tonne of its solid wastes generated, thus, slag disposal is a most important environmental concern with steel making industries (downtoearth.org.in). The utilization of steel slag as a by-product to another concern industries are cost-effective, sustainable for the whole environment and also it generates revenue for steel manufacturers and forms the foundation of a cost-effective worldwide industry (WSA, 2016). Threats caused by iron and steel industries are due to various forms of wastes generated — solid, liquid and gas (Sasi, 2013). In the 21st century, globally, climate change due to emissions of CO_2 is an important challenge for the iron and steel industries (https://www.worldsteel.org – accessed on 9 August 2016). According to resource consumption and pollution emission, iron industries are one of the biggest industries in India (Ahmad et al., 2015). Steel plant operations are bare to atmospheric pollution in the form of air, water, soil and noise pollution (Viswanathan and Gangadharan, 1996). During the steel manufacturing process a large amount of emissions release as output, like NOx, SO_3, dioxins and other heavy metals as pollutants introduces into the environment (Dai et al., 2015; http://cpcb.nic.in/SPMCharacterization.pdf - accessed on 15 July 2016; Viswanathan and Gangadharan, 1996). The major harmful metals of concern for India in terms of their environmental load and health effects are Pb, Hg, Cr, Cd, Cu and Al (A Position Paper, 2011).

Air Pollution

Iron and steel industries are an important source of air pollution emissions (Liu et al., 2013). Major pollutants of ambient air quality are Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), carbon monoxide (CO) and Particulate Matter (PM) (Chen et al., 2015). The combination of Carbon dioxide (CO_2) and methane (CH_4) headed for the greenhouse gas emission inventory in India (http://www.mse.ac.in/ManagingEnvironment/discussion.pdf - accessed on 30 June 2015). Particulate matters can significantly affect people's living environment in terms of air quality and visibility are composed of diverse chemical constituents (Seinfield and Pandis, 2006; Zhang et al., 2013). PM10 is the denotation for particles having an aerodynamic diameter less than or equal to 10 μm, comprising of road dust, smoke and pollen, whereas PM2.5 is for aerodynamic diameter less than or equal to 2.5 μm. PM2.5 has a greater tendency to be related to respiratory diseases than PM10 (Chen et al., 2015). The effect of air pollutants depends not only upon their concentration, but on the duration of exposure and composition of air pollutants too (Rai et al., 2011). The ability of particulate matter to create undesirable health effects in human depends on its deposition in the respiratory zone. The deposition rate depends on particle size, shape, and density of particulate matter. The size and aerodynamic are the most important characteristics that influencing the deposition of particles in the respiratory system (A – Report, CPCB, Bhopal, 2011). Iron and steel industry is an important source of air pollution emissions (Liu et al., 2013). Air pollutants from iron- and steel-making operation have traditionally been considered as an environmental and health hazard and consist of gaseous substances such as SO_2, NO_2, and CO (Rafiei et al., 2009). Polycyclic Aromatic Hydrocarbons (PAHs) are one of the emission pollutants that have turned into an important environmental concern during the past decades, for the reason that of their persistence, bioaccumulation and toxicity in the surroundings. It was also observed that the Several PAHs also exhibit mutagenic and/or carcinogenic properties (Netto et al., 2007). A major source of Polycyclic Aromatic Hydrocarbons (PAHs) was identified as iron-steel plants and due to the presence of coke ovens; PAH emissions of the integrated iron and steel plants are even higher (Zhao et al., 2006). Electric Arc Furnace (EAF) has been reported as one of the major polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDDs/Fs) emission sources of air pollutants (Lee et al., 2004). Jointly with sinter plants (Wang et al., 2003), they contribute 99% of the aggregate PCDD/F health risk to nearby population in thickly populated areas of a city in southern Taiwan (Kao et al., 2007).

Figure 2. Alarming levels of air emissions were observed in Bhilai Steel Plant in 2011 (CSE WEBNET).

Figure 3. Risk appraisal study: Sponge iron plants, Raigarh District (http://www.peasantautonomy.org/chhattisgarh-raigarh-sponge-iron-risk.pdf - accessed on 01 August 2016)

The emissions consequential from iron and steel plants have a straight impact on the environment and human health. The climate change, occurrence of the phenomenon of global warming, melting, ocean ice and increasing the amount of exposure to chronic diseases, etc. was associated with industrial emissions (Sasi, 2013). Gaseous air pollutants such as oxides of nitrogen, sulphur and troposphere ozone (O_3) etc. generates severe risk to human health and the environment due to their unfavorable effects (Dey et al., 2014). Emission monitoring exposed at Isdemir, the second biggest integrated iron and steel plant of Turkey, as the biggest cause of NO_x emissions with 6490 tonnes per year, followed by the entire steel industries in the region with 804 tonnes per year of NO_x. Generally, industries are the initial sources that are accountable for the pollution (Atimtay and Chaudhary, 2005). Emissions from iron production processes include a variety of air pollutants and have remained a great concern (Brook et al., 2004; Pope and Dockery, 2006; Tai et al., 2010; Zhang et al., 2010). Electric Arc Furnace (EAF) contributed the emission of pollutants at all the stage of steel making (ACMA, 1999). PM2.5 and PM2.5–10 fractions of the particulate matter are the pollutants of principal concern (Rickun, 1993) generated at every stage of the steel and iron production processes. It has been confirmed from many studies, that dust emission is an important source of ambient air particulate matter from iron and steel production (Dai et al., 2015). The wide range of pollutants associated with the production process, need to quantify with their potential impacts on the ambient air concentrations of the pollutants and human health (Brunekreef and Forsberg, 2005; Dockery, 1993; Katsouyanni, 2005; Owoade et al., 2015). Heavy metals such as As, Cd and Cr, even at trace amounts, are toxic and has been reported to be constituents of particulate matter associated with iron and steel production (Cohen et al., 2004). The production of steel accounts for approximately contributes around 6 % - 7% of total anthropogenic emission of CO_2 (Ahmad and Patel, 2012; Alvi et al., 2013).

New Delhi, May 8, 2014: It Was reconfirms by the World Health Organization (WHO), and the latest urban air quality database released that most Indian cities are becoming death traps for the reason that of very high air pollution levels. India appears among the group of countries with maximum particulate matter (PM) levels and also, its cities have the maximum levels of PM10 and PM2.5 when evaluate with other cities (cseindia.org).

Raipur, Oct 28 (IANS), notices issued by the Chhattisgarh Environment Conservation Board (CECB) to fifteen steel production units in the Chhattisgarh state for defying pollution control norms. These small size industries are located at Urla, Siltara and Borjhara industrial areas on the periphery of Raipur, have not followed and utilized pollution control measures neither using electro-static precipitator (ESP) — an air pollution control device — during night period of operations. As per government officials, about 145 industrial units in this industrial area are very close to Raipur is not with pollution control equipment. Near Raipur, Urla, Siltara and Borjhara areas are located in close proximity to the National Highway (NH) 200 on the Raipur-Bilaspur road is home to forty three sponge iron plants, about a hundred rolling mills and a few ferro-alloy units. Experts declare so as to about one million people from Raipur city and its forty neighboring villages were suffering from severe respiratory diseases and skin cancer due to direct exposure to polluted air, water and dust-mixed grain and vegetables due to the presence of dense industrial activities (Thaindian News, 10/28/2009). According to a study the students of a government school near Godawari Power and Ispat Limited (GPIL) in Raipur are heavily affected by dust emissions from plants. The plant dumps a mixture of sponge iron and char with height for separation and making dust airborne (downtoearth.org.in). Considerable air pollution from stacks and emissions from solid waste dumps, are the two types of pollutants noticeable from sponge iron plants in Raigarh district. (http://www.peasantautonomy.org/chhattisgarh-raigarh-sponge-iron-risk.pdf - accessed on 01 August 2016).

Heavy metals released from the sponge iron plants, are highly toxic, to the atmosphere during handling of iron ore and from the stacks of steel plants, some of them—chromium (as Cr^{+6}), cadmium, nickel, are human carcinogens, Iron along with other carcinogenic heavy metals tends to increase prevailing cancer risk, although the toxic effects of heavy metals are varied and may often manifest over a long period of exposure, sometimes several years, as in the case of cancer (http://www.peasantautonomy.org/chhattisgarh-raigarh-sponge-iron-risk.pdf - accessed on 01 August 2016).

Central pollution control board (CPCB) Bhopal has reported the percentage of heavy metals in suspended particulate matter (SPM) at Raipur and Raigarh city in Chhattisgarh state — In Raipur city, the heavy metals were found in the range of 0.90-6.52% of SPM, on eight hourly basis and 1.17-2.32 % of SPM on a 24 hour average basis and in Raigarh city, the heavy metals are found in the range of 0.32-1.85 % of SPM, on eight hourly basis and 0.43-0.89 % of SPM on a 24 hour average basis. The higher values of Fe are confirming the sponge iron industries are the main contributor of ambient air pollution (CPCB, 2010 – 11).

Heavy Metal Leaching Pollution

The iron and steel industries, disposes huge amounts of slag as by product, as till date it cannot be utilized hundred percent and converted into huge dumps surrounding to plant site and encroaching on the valuable land. Iron and steel industry slag is generally consists of calcium, silicon and iron and also contain trace amounts of probable toxic elements, particularly chromium and vanadium, which can be released from slag (Chaurand et al., 2006). BF slag is considered unfriendly to the environment when present in fresh because it gives off sulfur dioxide and, in the presence of water, hydrogen sulphide and sulphuric acid (Kachhap, S., 2009-10).

Soil served as a receiver and known as contaminated if received other substances, identify as contaminants (Gowd et al., 2010). For the transportation of chemical substances and elements in the atmosphere, hydrosphere, and biosphere soils can also act as a natural buffer (Yaylalı-Abanuz, 2011). Soil contamination due to pollutants released from steel production is one of the gravest problems in the world and have long period consequences on human life (Antoaneta et al., 2011). With innovations and rapid advancement of steel industry a variety of hazardous pollutants are being released such as heavy and toxic metals (As, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Sb, Se, V, and Zn) smelting and tailings, and are getting deposited in soils in the region of industrial activities causing severe pollution and hence, deteriorating soil quality. Iron and steel manufacturing produces a significant amount of solid wastes containing toxic heavy metals (Ene and Pantelica, 2010; Ene et al., 2009). The liberation of toxic heavy metals from the dumps or landfills by weathering (or due to leaching) leads to pollution of the surrounding soil, as well as surface and ground waters (Geiseler, 1996; Motz and Geiseler, 2001; Proctor et al., 2000; Sofilic et al., 2013) have concluded that the release of constituent from BOF slag was of no consequence in terms of environmental impact. Plants collect environmental pollutants by atmospheric depositions to their parts and also in root uptake from the soil. Pollutants' physicochemical properties, plant characteristics and environmental conditions govern the intensity and level of accumulation (Zhao et al., 2006).

Due to the rapid and man-made activities to meet the population demand, such as industrialization and urbanization, the concentration of heavy metals in soils is constantly increasing (Li and Feng, 2010). The concentration of heavy metals in soils, therefore much depends on the retention power of the soil, which affecting soil particle surfaces, physical, chemical properties of soils and chemical properties of heavy metals (Soriano et al., 2012). Heavy metals could be remaining in soils for a much extended time. At a certain level, heavy metals are necessary for a human body, although they also are capable of causing toxic effects if exceeded the permissible limit (Abdullah et al., 2014).

In several parts of the country steel plants are causing severe water anxiety (downtoearth.org.in). A conclusion was drawn with the analysis of topsoil samples for pollution index and results indicated that urban soils are moderate to seriously polluted by Cd, Zn, Cu, and Pb in a steel industrial city (Anshan), Liaoning, Northeast China (Qing et al., 2015). Also the impacts of the steel plant were described in terms of the rate of the fallout of the settleable dusts in the locality of the steel plant, and the levels of occurrences of particular toxic metal, (Bi, Cd, Co, Cu, Ni, Pb, Sb, Sn, Zn, Cr, Mn, Mo, B and Be) (http://shodhganga.inflibnet.ac.in/bitstream/10603/31433/8/08_chapter%203.pdf – accessed on 22 August 2016)

Role of Sponge Iron Plants

For the production of steel, sponge iron is an intermediate product used in the manufacture of wrought iron and as a substitute of scrap during steel making (Bhojwani and Bagga, 2016; http://www.cpcb.nic.in/upload/NewItems/NewItem_102_SPONGE_IRON.pdf - accessed on 05 August 2016) thus in last the 20 years about hundreds of sponge iron industries has been started in the central India (http://www.peasantautonomy.org/iron-factories-resistance.html - accessed on 8 August 2016). Since 2003, India is the largest producer of sponge iron with production growing from 7.67MT in 2003 to 17.31 MT in 2014 accounting for 23% of world's production (Bhojwani and Bagga, 2016).

Discussion

Industrialization and environmental pollution with technology have gone ahead to affect human health (Yagdi et al., 2000). Air pollution from industries is aesthetically offensive and can be a true health hazard to humans as well as to vegetation (Janick, 1986). Heavy metals are commonly released into the air from industrial emissions, the use of fossil fuels for heating systems and means of transport exhausts (Onder et al., 2007). Iron and steel industries are the main causes of air pollution emissions. It was found in an analysis that air pollutant levels were higher surrounding to steel plant. Also, it was concluded that, staying close to the plant for a small period of time was related to higher pulse rate than staying at a site farther than away from the plant even though several pollutants were also associated with increased pulse rate. These conclusions recommended that air quality in an inhabited area close to a steel plant may influence cardiovascular physiology (Liu et al., 2013).

Minimization of waste produced in the blast furnace is principally related to the reduction in slag volume. High ash content of the Indian coal is to a very large extent and is answerable for high slag volume in the process of blast furnaces and therefore, decrease in the coke rate would decrease the waste generation (Sinha and Agrawal, 1996). Leaching increased along the slag ageing period, thus; reuse of slags without a proper previous treatment or the uncontrolled dumping can have negative effects on the environment in the long term. Thus, the pre-treatment of slag or its stabilization before reuse is recommended, even for low value applications (Gomes and Pinto, 2006).

Raipur as capital and Raigarh in Chhattisgarh state have witnessed higher industrial development resulting in heavy air pollution in these cities and regions having mainly steel and sponge iron industries, contributing particulate matters (PM) a pollutant in the ambient air. Health related complaints have been lodged with state/central authorities (A – Report, CPCB, Bhopal, 2011). For the past 15 years, in Raigarh, Jindal Steel Plant Limited (JSPL) has been dumping their generated slag and waste from its sponge iron units at its dump site which is located at a distance of five km from the plant and consequently, during rainy season, pollutants from the site reach Parsada village, and at the receiving end is farmers whose crops suffer (downtoearth.org.in). The concentration of heavy metal present in an analysis indicated that the leachate produced by uncontrolled and unscientific disposal of steel slag wastes contaminates soil samples of the identified area of Chhattisgarh (Tiwari et al., 2015).

The environmental impact of the iron and steel sector occurs mostly in raw material mining and handling. Maximum weightage could be assigned to coke-making and blast furnace processes, which are highly polluting and resource-intensive (downtoearth.org.in). The iron and steel industries dump their poisonous waste everywhere. Iron acts along with other carcinogenic heavy metals to enhance cancer risk. The toxic properties of heavy metals are varied and may over and over again manifest over a long-lasting period, now and then several years, as in the case of cancer. SIUs also emit oxides of sulphur and nitrogen and hydrocarbons. The emission pollutants are also expected to enhance the incidence of respiratory tract complaints, e.g., coughing, phlegm, chronic bronchitis and also aggravate asthmatic conditions (peasantautonomy.org).

Conclusion

The heavy metal and SPM pattern clearly indicating that the ambient air quality in the Raipur city is getting degraded with respect to heavy metal (mainly Iron) concentration which is a major point of concern. In Raipur city, the trend shows that the pollution is generated from industries in a Siltara industrial area and getting dispersed. The heavy metal concentrations are higher at night during stable environmental conditions. In Raigarh city, topography plays major role in the dispersion of pollutants (A – Report, CPCB, Bhopal, 2011). The same condition can be considered for Korba and Raipur industrial region, although Durg – Bhilai industrial region has some better conditions. Many times the industrial solid waste from iron and steel plants is dug or dumped into the ground. It causes leachate generation and polluting land and consequently ground water sources also.

Emissions from these industries along with the disposal or huge dumping of industrial solid waste to the environment have made our precious air and land environment polluted. The steel industry can adapt to the stack emissions norm of 20 microgram/Nm^3 with ease. To eliminate the toxic emissions, only non-recovery coke ovens should be allowed. Hence it is essential that, we must protect our environment from these pollutions, without compromising the development of our people of Chhattisgarh through the industrial revolution.

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