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Genesis, Uses and Environment Implications of Iron Oxides and Ores

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Additional information is available at the end of the chapter

Abstract

Iron oxides are chemical complexes which occur naturally, comprising iron and oxygen. Here, together, 16 types of iron oxides and oxyhydroxides have been identified. These two components of oxides are widely spread naturally. They are vital to humans and useful in most geological and biological activities. In addition, they are useful as pigments and catalyst in industries and hemoglobin in blood circulation. The interplay and conversion of these components from one form to another are essentially controlled by bacterial species. These contain 70 and 72% iron, respectively. Furthermore, iron ores are classified in terms of occurrence. Banded iron formation (BIF) comprises 15% iron, comprising minerals of iron that are bedded besides silica. Beneficiation processes of iron ore generate dust in the atmosphere, acid mine drainage in the ecosystem and metallic iron for steelmaking. Beneficiation process requires dissolution of minerals surrounding the ore and the release of metals and cement matrix into water courses. These generates acid leading to acid mine drainage. Therefore, there is a need for impact assessment of the environment in the planned beneficiation cycle. Sustainable beneficiation must be done to reduce impact on the natural, social or economic environment.

Keywords: genesis, uses, environmental implications, ochre, oxides of iron, iron ore

1. Introduction

The genesis, uses and environmental implications of iron oxides and ores remain a topic of interest to academics, industrial players and environmentalist. Oxides of iron are chemical compounds widely spread naturally, comprising iron and oxygen. Here, two components of oxides are widely spread naturally. They are relevant to humans and useful in most geological

and biological activities [1]. In addition, they are useful as pigments and catalyst in industries and hemoglobin in blood circulation. Iron oxides that are economically viable in natural and beneficiated forms are considered as second to oil and gas in relation to demand and utility in the global market. They occur as divalent compound, trivalent compound and a combination of both. The interplay and conversion of these components from one form to another are essentially controlled by bacterial species. These bacteria use iron and reduce trivalent iron oxides to divalent form during metabolism.

Different geological conditions control the spread of iron ore deposits worldwide. They occur in basins of sedimentation, with eroded, deep-seated intrusive and where deep tropical weathering conditions prevail. Magnetite deposits occur in the deeply dissected regions of plutonic intrusions in North America [2, 3].

Several authors have provided information in the environmental outcome of exploration and exploitation of iron ore. These include pollution of the atmosphere and ecosystem courses of water. Pollution of the atmosphere involves release of poisonous gases such as nitrous oxide, carbon dioxide, carbon monoxide and sulfur dioxide. Pollution of the ecosystem involves release of metal load into courses of water. While there is limited remediation programme on the former, the latter has gained considerable attention, and elaborated ochre is a product of the aqueous oxidation of iron and oxides of iron [4–7].

2. Genesis

Natural iron oxides occur extensively and are obtained from deposit of various types. Hematite is mainly sourced from iron ore of sedimentary origin inclusive hydrothermal, metamorphic and volcanic deposits. Mafic and ultramafic rocks are linked with magnetite. This is also associated with skarn-type metamorphic deposits. Products of weathering such as limonite, ochre, sienna, umber and goethite exist in gossans. In addition, they are obtained from sulphide minerals and other iron-rich rocks [8].

Deposits precipitated from seawater are used in production of umber. These are located on the seafloor. Sulphide deposits are known to provide ochre and iron oxide coatings via oxidation. Black pigments are provided by magnetite deposits besides red and yellow ochre and iron oxide coatings derived from weathering of magnetite. Hematite deposits outcrop around the margins of the great sedimentary basins worldwide. There are oxide-rich deposits of igneous and metamorphic origin in Sweden. In Africa, good quality iron ores lie near the Mediterranean in Morocco and Algeria. There are extensive deposits in Brazil, India and China. Iron ore deposits are distributed widely in different geological formations [9].

The largest concentrations of ore are found in Precambrian age banded sedimentary iron formations. These formations make up the bulk of the world's iron ore incomes. These ores vary from hard blue massive type to soft, friable or schistose texture. The orebodies generally stand out as ridges with the ore both on the crests and on the flanks. Small patches are enriched by manganese derived from surface solution. The iron content extends from 64 to 68% after

beneficiation. The leached out iron could be carried downwards to be precipitated as bodies of ochre and iron oxide coatings within the existing sedimentary rocks. This product is a soft earth mixture of hematite, limonite and goethite from which various red and yellow ochre and iron oxide coatings can be extracted [10].

The main product is a dark red hematite variety. Some ore deposits consist of magnetite with occasional hematite; varying amounts of sulphide occur mostly as pyrite and pyrrhotite with minor amount of chalcopyrite. The ore is composed of ferriferous oolites and grains of quartz bounded by a cement of clay minerals or of chlorites and carbonates. The oolites consist of iron hydroxides or limonite, with variable proportions of silica, alumina and phosphorus. The strikes of the orebodies are sometimes in accordance with the iron formation and sometimes discordant. The high-grade ore could be magnetite that is partially oxidized at the outcrops to hematite, with minor quantities of silicate minerals, anthophyllite and chlorite [11].

Deposits of iron may be categorized under the following: magmatic, sedimentary and metamorphic. In some regions of the world, the major sources of high-grade iron ore are derived from magmatic iron and metasomatic hydrothermal iron deposits. These especially the skarn-type iron deposits are mainly associated with intermediate-felsic igneous rocks, with only a minor proportion related to mafic intrusions. The iron redox cycle is a substantial process that exists in most terrestrial environments, which can be conducted by both abiotic and microbial processes. In anoxic, pH-neutral environments, microbial Fe(II) oxidation is driven by either nitrate-reducing bacteria, photoferrotrophic bacteria or neutrophilic microaerophilic bacteria [11, 12].

Microbial Fe(III) reduction forms the other component of the Fe cycle, generated by intracellularly by magnetotactic bacteria [12] or outside of the cell wall by dissimilatory iron-reducing bacteria. These combines with the oxidation of organic substrate or hydrogen with the reduction of poorly crystalline, short-range ordered Fe(III) minerals (e.g. ferrihydrite) [13]. This can lead to the development of many different iron mineral phases and compounds including goethite, magnetite, green rust and siderite (Fe_2CO_3). The mineralogical composition of these products of reduction depends on geochemical parameters, inclusive Fe(III) reduction rate, pH, temperature and the availability of electron shuttle [14, 15].

Based on redox condition, magnetite can donate or accept electron in different metabolic processes involving Fe. In this respect, knowledge of the mineralogical outcomes of biomineralization characteristics can help provide signatures of microbial reactions with fluid, rocks, mineral deposits and subsequent diagenesis. Banded iron formation (BIF) is a chemically produced rock of sedimentary origin. This was precipitated in Precambrian time, comprising intercalated microcrystalline quart, iron oxides and silicates rich in iron. In line with depositional settings, the BIFs fall into Algoma type and superior type [16–18].

The constituents are discontinuous silica- and iron-rich bands with similar mineralogical properties of Fe, chert and carbonate minerals. Arc/back-arc basins or intra-cratonic rift zones host the Algoma type, and the latter is hosted by clastic carbonate rocks linked with shallow marine environments. As the main mineral constituents of BIFs, magnetite has been broadly reported for BIFs' depositional systems, mineralization characteristics and possible microbial involvements. Chemical and sedimentary methods in normal seawater could produce marine

Fe-Mn oxides/oxyhydroxides. These are formed by precipitation of micron range particles of these components onto rock substrates at seabed [19–21].

The Itakpe iron ore deposit in Nigeria with an estimated reserve of about 200 million ton was discovered in 1977. The areal extent of this deposit spans about 3000 m in length inclusively in several layers of ferruginous quartzite. Tectonically, this deposit is located at the southern flank of the Itakpe-Ajabanoko anticline with host rock and ore layers striking sublatitudinally and slightly bending to the north and dipping southwards with local minor-fold complexes. Itakpe iron ore deposit comprises variable constituents of hematite and magnetite and particle sizes. This deposit with an Fe content of 35% consists of fine ores occurring in thin layers and coarse-grained mixed components. Direct-reduced iron (DRI) is the direct reduction of iron ore to iron n steel making. The DRI constituents of the pellet include: slag containing oxides of calcium, magnesium, alumina, silica. DRI pellets contain 67% Fe and 3% silica. In establishing a steel plant, availability of economically beneficiated iron ore deposit stands out as the main factor. The concentrates required at Ajaokuta and Delta steel plant would be supplied by the Itakpe iron ore deposit [22–25].

2.1. Uses

A mixture of ferrous or ferric oxides constitutes iron oxides provided for pigments. These may contain impurities of manganese oxides, clay and silica. Oxides of iron remain one of the pigments of natural origin inclusive titanium dioxide. They are highly valued because they possess non-toxic, inert, opaque and weather-resistant properties. Oxides of iron constitute the main component of products in the pharmaceutical industry, paint industry, plastic industry, ink industry and cosmetic industry. Oxides containing mica provides anticorrosion properties. Natural pigments which qualify for these applications are limited in occurrence. Thus, synthetic iron oxides obtainable from iron compounds have better uniformity, purity of color, consistency and strength [26, 27].

The physical characteristics of these oxides are more valuable than chemical composition. The suitability of a material for pigment application is dependent on grindability, color uniformity and strength of tinting. Besides these properties, chemical purity is also important for its application in the pharmaceutical and cosmetic industries. Calcination of pyrite and siderite provides iron oxides which meet characteristics for these applications. Other beneficiation processes for commercial production of pigments include decomposition of iron compounds by thermal method, oxidative precipitation of iron salts and reductive process on organic compounds [28, 29].

Synthetic pigments override natural pigments due to their proximity to the place of use and meeting required specifications. The use of magnetite in dense medium separation is based on its physical properties: specific gravity and magnetism. Thus, magnetite could be recovered and used again. Magnetite provides separation of high-density minerals and washing of coal. The banded ores contain thin bands of hematite and magnetite alternating with bands of quartz schists, jasper and iron silicates with occasional bands of siderite. In more metamorphosed varieties, hornblende, olivine and garnet are present. Sulfur and phosphorus are low. Concentration is achieved by roasting to reduce the hematite to magnetite, crushing and magnetic separation followed by sintering and briquetting [29, 30].

Iron oxide pellets are used as the raw material in shaft furnace smelting. This is due to their uniformity in size, enormous strength and excellent permeability. However, production may be hampered by the rupture and fragmentation of pellets. Strength of pellet is closely connected to the modification of internal structure. In high-temperature reduction process, the strength changes are led mainly by internal stress. Phase alteration of oxides of iron in process of reduction may generate internal stress. To avoid this, magnetite should take the place of hematite crystalline in the pellet oxide roasting process. This will reduce volume expansion during reduction process [31–33].

Direct-reduced iron (DRI) has been carried out in recent times to provide justifiable metallurgical operations. DRI possesses enormous benefits because it does not depend on coke-making and sintering. Where coke-making and sintering are fronted at the conventional blast furnace, then ironmaking ends up being a costly process and is consistently causing environmental concerns. The DRI procedure consists of reduction of iron oxide by carbothermic method and converted natural gas. In this process, volatiles are directly liberated during coal devolatilization besides carbon monoxide regeneration from coal char. This process provides application prospect for the high volatile coals, which were ordinarily impractical in the steel industry. Extensive work has been reported on reduction of iron ore and coal-ore mixtures and its kinetics [34, 35].

Optimization of the coal-based DRI process requires understanding of the thermal properties of the coal-ore mixtures and mechanism reactions of reduction, which have still not been well understood. It is therefore necessary to have an insight into fundamental mechanisms for these complex reactions. The Itakpe iron ore is the deposit of the main concern to the Nigerian steel industry. The ore comprises substantial quantity of quartz and silica present itself in parallel layers to each other. About 29–37% Fe is contained in the ore grade, thus averaging 35% Fe. High flue dust losses are the basic characteristics of constituents which provide marked interruption during reduction. In addition, this could lead to attenuated furnace operation. Reducibility and clustering behaviour are significantly influenced by additions of 5% slaked lime to Itakpe iron ore pellet [36, 37].

The consequence of iron ore tailings (IOT) on modification of cement tropical black clay was considered. The naturally occurring soil was worked on using 4% cement and 10% IOT per soil dry weight. Samples of tested soil compressed with British Standard measurement mechanism were exposed to catalog, sieve examination, compaction and shear strength parametric study. The outcome of laboratory study displaying attributes of the improved soil was enhanced when tested with cement-IOT blends. Experimental results expressed attenuation of the satisfactory fraction, attenuation in liquid and plastic limits and enhancement in optimum dry density, with a reduction in optimum content of moisture (OMC) besides attenuation in shear strength rate of the natural soil [38].

2.2. Environmental implications

The role of ochre and oxides of iron in copper and zinc adsorption has been studied by [39–48].

Ochre and oxides of iron present in aqueous metal load are known to be good adsorbents. Heavy metal contaminants especially heavy metal load in the aquatic environment, discharged

by acid mine drainage and treatment plant liquids, constitute the principal derivatives of tarnished water channels. Limited reports of heavy metal removal exist. However, the utilization of oxides and oxyhydroxides inoculated with sulphide of zinc within sulfidic-anoxic setting is a new dimension of research [39, 40]. This report centred on investigating heavy metal load removal onto ochre and iron oxide coatings from virtual wastewater related to effluents. At ambient temperature, batch mode techniques involved inoculating sulphide containing heavy metal into mineral system of ochre and iron oxide coatings [41].

pH of solution, quantity of metal at the onset of reaction, concentration of adsorbent and reaction time were variables investigated (**Table 1**). There was a strong understanding that goethite-ochre and iron oxide coatings exhibited a linear increase in the adsorption of heavy metal load as solution pH was increased. In addition, quantity of adsorption increased with increase metal concentration [41–44].

Some mineral systems including ochre and oxides of iron coatings confirmed neither promotive nor non-promotive adsorption of heavy metal load throughout the series of concentration of particle investigated. Adsorption of heavy metal load by ochre and iron oxide coatings revealed a complex attitude throughout the period of aging investigated. Performance of adsorption was dependent on availability of different sites of reaction [45].

Adsorption of heavy metal load was examined by means of single and mixed mineral systems containing ochre and iron oxide coatings within sulfidic-anoxic environment in the

Characteristics	Weight (%)
SiO_2	0.30
Al_2O_3	0.18
FeO	62.62
MgO	0.03
Na_2O	0.00
CaO	0.23
MnO	0.06
K_2O	0.02
Cu (ppm)	0.14
Zn (ppm)	0.18
Surface area (m^2/g)	97.00
% (<1000 nm) colloid	1.83
Particle size range (μm)	0.01–100.00
pH $\pm \sigma$	3.00
Point of zero salt effect (PZSE)	7.13

Table 1. Characteristics of Parys Mountain ochre, United Kingdom [46, 47].

characteristics of wastewater obtained from abandoned mine pits at Parys Mountain in the United Kingdom. Bodies of water are the receivers of these contaminants. In these bodies of water, human activities including fishing exist. Effort was made to bring down the levels of heavy metal load intake in the bodies of water by means of ochre and iron oxide coatings. These were verified with the mine liquid waste for adsorption characteristics at different pH, concentration of solid and reaction time. In addition, levels of saturation of hydroxyl chemically bonded components were modeled. Reactions by batch techniques at ambient temperature provided ochre and iron oxide coatings adsorbed more heavy metal load (**Figure 1**). In addition, heavy metal load adsorbed on oxides of iron displayed increases in adsorption with increase in pH [46, 47].

There was cross-cutting pH characteristics of heavy metal load adsorbed on goethite at pH = 7. These provided similar reduction of metal characteristics at the crossover pH. Differences in heavy metal load reduction may be aligned to linkages between adsorbate and water molecules attached to adsorbent and direct attachment of adsorbate to adsorbent. Non-promotive effect of, i.e. attenuation in metal reduction with enhancement in concentration of particle, was detected in ochre and iron oxide coatings. This feature may be aligned to enhanced aggregation of the ochre and iron oxide coatings of particle sizes. Features of aging progress as reaction time was increased. This may be aligned to the availability of thiol and hydroxyl components and chemical sites of responses. There is no link to stable introduction of hydroxyl group to species of copper and zinc that could meaningfully account to the reduction of these metals [48].

Litter by heavy metals of copper and zinc provided by acid mine drainage and liquid waste treatment are the leading sources of blotted water chemistry. Metal plating, mining and painting cause release of heavy metals of copper and zinc. These metals become a serious health problem. This is because they are dogged and have harmful effect on the environment. Heavy metals of copper and zinc are required in small quantity element that is essential for nutrition [46, 47].
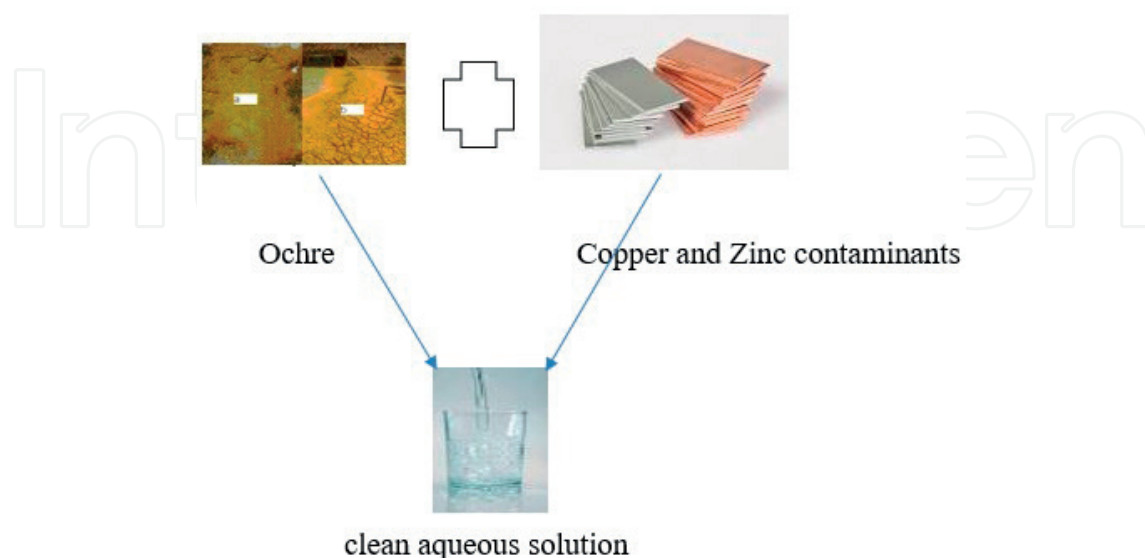

Figure 1. Graphical summary for ochre interaction with copper and zinc ions.

However, when available in overdose, it may be noxious. This could pose adverse danger in groundwater and surface resources as they build-up in living organisms [45]. It is widely known that surplus of heavy metals of copper and zinc provides depression, lethargy and neurological disorder signs such as nervous confiscations and increased dehydration. Therefore, reduction of these metals from water courses is needed. Anthropogenic activities release metal load into bodies of water. These metal loads damage the ecosystem and are toxic to humans and other forms of life. Chemical solution and appropriate sorbents determine the availability of dissolved metal species [44].

Reduction of copper and zinc ions from solutions of aquatic nature is governed by the makeup of the solution. These include the outcome of hydrogen ion concentration and the number of solid particles in the wastewater. pH remains an important factor in reduction of metal ions from the aqueous environments. The amount of dissolved metal in solution is measured by pH. Another effect of pH includes hydrolysis characterization and surface charge. Lower pH attenuates hydrolysis and enhances metal build-up in the solution. Adsorption of heavy metals of copper and zinc is controlled by anion nature and the external layer of the adsorbent [43].

Adsorption related to solute water molecule attachment attenuates as particle concentration increases. Adsorption related to solute direct attachment to adsorbent does not significantly increase in some cases as adsorbent quantity increases. When adsorption is enhanced as particle concentration increases, then promotive particle concentration effect is reported. The reasons for the promotive adsorption effect by concentration of solid particle remains are uncertain. Ionic species available in solution are influenced by the forces at work at the mineral-solution interface. This is controlled by formation of high and newly formed reaction sites [42].

However, adsorption of metalloids and metals does not have a lined-up rapport with respect to these features. The mechanisms of adsorption accountable for heavy metal reduction provide both slow and fast steps of reactions. The slow reaction period is accredited to slow diffusion of interparticle and advanced activation energy when linked with the fast sites of metal reaction. The fast reaction period may be distributed to adsorption by electrostatic pull. Comparable procedures include adsorption that is specific to adsorbent external layer and formation of an insoluble salt in many respects. In naturally controlled systems, adsorption generally takes place on external surfaces of ochre and iron oxide coatings of mineral surfaces [41].

These processes could piece together, and the prevalence of one is hard to determine. This may be characterized by several uncertain mechanisms. Increase in heavy metal reduction from solution as initial concentration of metal increase has been reported. This capacity of adsorption increase in kith and kin to the concentration of metal ions can be clarified with the high columbic force for mass transfer. The presence of ochre and iron oxide coatings attenuated heavy metal removal over the series of pH (i.e. pH = 4–8) investigated. Increased ionic strength (i.e. 0.00–0.1 mol/kg) and concentration of solid (i.e. 0.002–0.01 kg/L) presented a multifaceted response. The uncontrollable discharge of liquid waste comprising heavy metal load into courses of water has occasioned in the degradation of watercourse water chemistry [40].

Thus, reduction of heavy metal load from sewages, before their issue to the ecosystem, is a significant problem of contemporary wastewater handling. Metals are routinely different

from other noxious pollutants. They cannot be decomposed and can post up in tissues of humans. Heavy metals of copper and zinc are major pollutants usually found in effluent discharge. Adsorption to ochre especially in their natural states is a fundamental process providing the transport, degradation and biological activity of organic compounds in the ecosystem. Although often regarded as instantaneous for modeling purposes, adsorption may in fact require many months to reach equilibrium. Heavy metal reduction is governed by chemical composition of the aqueous system: solution pH, solution ionic strength and solid particle concentration, as well the reaction time of the solid component in the waste-water [39].

However, the particle size of ochre and iron oxide coatings in adsorption tests could significantly affect the adsorption features related to the tests. Reaction associated with breaking of molecular bond of water linked to reaction pattern is ruled by solution pH and solution ionic strength. Attenuation in metal reduction in ochre medium as solution ionic strength increases supports metal attachment to water molecules in the adsorption process. In the other way around, direct attachment of adsorbate to the adsorbent is involved [40]. The solute contained in a solvent provides the solid concentration effect for mechanism of sorbate reduction, whereby metal reduction models attenuate as solid-to-solvent ratio increases. Different sites of reaction could be created as contact between the sorbate and adsorbate structures is increased [41].

Here, the effect of ochre and oxides of iron on reduction of heavy metal in relation to composition of solution and aging has been discussed. The impacts of various factors, such as reaction time, ionic strength, adsorbent size, initial solution pH and solute-solvent ratio on the adsorption quantity were studied. Models of adsorption kinetic provided illustrated that adsorption quantity of ochre and oxides of iron was dependent on pH (i.e. pH = 4–8), solute-solvent ratio (i.e. 0.002 kg/L to 0.01/L), the reaction time (i.e. 24–720 h) and the sizes of the ochre. The hydronium ion regular diffusion coefficient in the presence of ochre and oxides of iron was enhanced when anoxic solution of iron sulphide was introduced into the reaction system. The net movement of adsorbate to external layer of the adsorbent decreased with contact time increase [42].

Reactions were in three-step processes: chemical species involved were discrete and separate, chemical species were bridged and adsorption of adsorbate on the inner surface of the adsorbent, and these provided the basis for the kinetic models used. The arsenite reduction by the ochre and oxides of iron was altered by the presence of thiol group and submits a non-promotive Cp effect (i.e. adsorption reduced with increase in Cp). Ochre and oxides of iron provided increased arsenite adsorption as reaction time increased until 288 h.

In another study [43], ochre and oxides of iron systems were examined to understand their consequence on heavy metal reduction. Isotherms discovered metal reduction by ochre and oxides of iron which were controlled by ochre size, solution pH, ionic strength, particle quantity and reaction time. Mineral mixtures containing ochre and oxides of iron provided diverse adsorption characteristics from the single ochre and oxides of iron mineral systems. These oxides attenuated heavy metal removal over the series of pH (i.e. pH = 4–8) investigated. Increased ionic strength (i.e. 0.00–0.1 mol/kg) and adsorbent quantity (i.e. 0.002–0.01 kg/L) displayed an intricate response [43].

This study was required because the reckless release of wastewater comprising copper and zinc into water passages has caused dilapidation of stream water chemistry. Thus, reduction of heavy metal ions from sewages, before they are being emptied to the ecosystem, is a key issue of modern wastewater control processes. Metals are usually diverse from other toxic pollutants. They cannot be decomposed and can build up in living tissues. Heavy metals of copper and zinc constitute major pollutants usually located in effluent discharge. Adsorption to natural solids like ochre, oxides of iron and clay minerals is a fundamental process influencing the transport, degradation and biological activity of biological compounds in the ecosystem. Although often regarded as instantaneous for modeling purposes, adsorption may in fact require many months to reach equilibrium [44].

Again, heavy metal reduction is controlled by chemistry and makeup of the aqueous solution, solution pH, ionic strength and adsorbent concentration, besides the reaction time of the solid stage in the wastewater. However, the adsorbent particle size of such usual adsorption methodology could alter the adsorption features involved in the report. Reactions comprising the breakage of bonds in a water molecular form are a function of solution pH and solution ionic strength. Lowering of metal reduction in solution as solution ionic strength increases provides adsorbent water molecular attachment. The opposite describes direct attachment of adsorbate to the external layer of the adsorbent [45]. The quantity of solute-solvent ratio (i.e. solid concentration) consequence is a usual metal removal mechanism, whereby metal reduction in solution isotherm attenuates as quantity of solute-solvent ratio increases. Diverse reaction sites could be formed as contact between the adsorbate and ochre and oxides of iron mineral systems was increased. This study aimed at discovering the outcome of interacting ochre and oxides of iron mineral systems and the mixture components with clays on adsorption behaviour of heavy metals of copper and zinc in relation to chemical composition of solution and reaction time [46].

Figure 2. Graphical summary for mercury interaction with ochre.

Figure 3. Graphical summary for lead interaction with ochre.

The influences of various factors, including reaction time, solution ionic strength, adsorbent size, initial pH and solid quantity on the adsorption quantity, were studied. Adsorption of heavy metals of copper and zinc was looked at by means of single minerals of ochre and oxides of iron and their mixed mineral components with clays in sulfidic-anoxic state. Attempt was completed to lower the quantity of metal levels in these mine pits before release into the ecosystem [47].
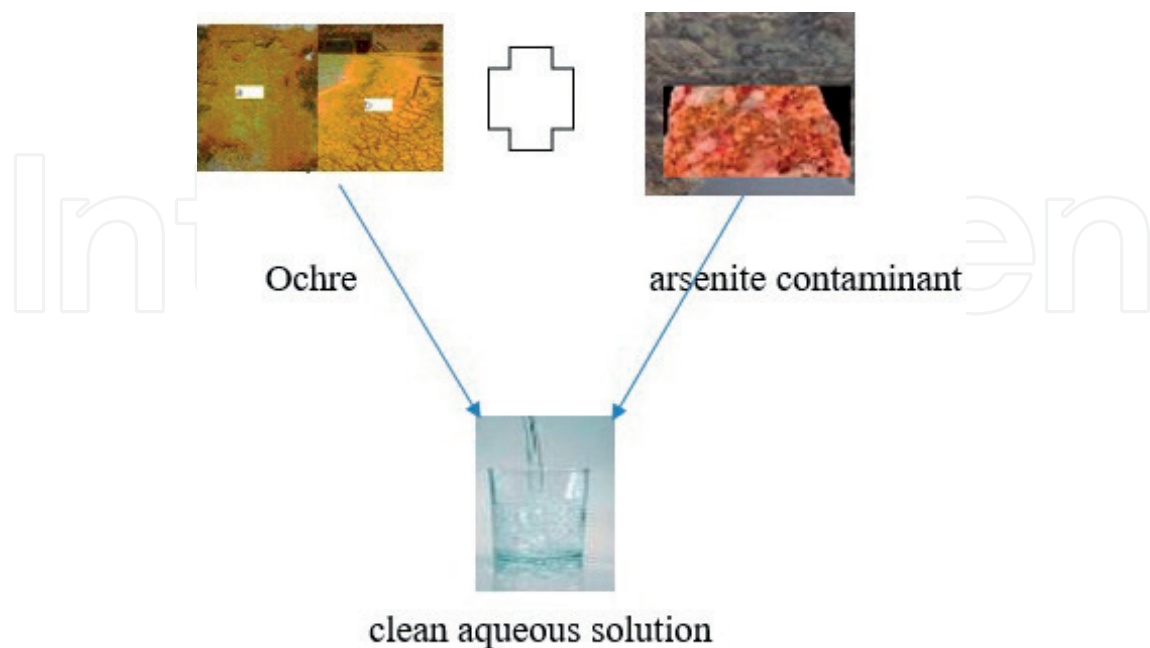

Figure 4. Graphical summary for arsenite interaction with ochre.

Ochre and oxides of iron and their mixtures with clays were tested with the mine waste-water for description of metal reduction in these mine wastewaters. This was conducted at adjustable solution pH, solid quantity and contact time. In addition, levels of saturation of complex compounds containing hydroxyl group were modeled. Batch responses directed at ambient temperature disclosing all mineral systems reduced metal load. Also, metal adsorbed on oxides of iron unveiled enhanced adsorption as solution pH was increased (**Figures 2–4**). There was cross-cutting consequence of heavy metal load attached to ochre and oxides of iron at about pH = 7. These cross-cutting features indicated analogous metal reduction characteristics [48].

3. Conclusions

Genesis, uses and environmental implications of iron oxides and ores have been considered in this chapter. Natural iron oxides occur extensively and are obtained from deposit of various types. Hematite is mainly sourced from iron ore of sedimentary origin including hydrothermal, metamorphic and volcanic deposits. Mafic and ultramafic rocks are linked with magnetite. This is also associated with skarn-type metamorphic deposits.

A mixture of ferrous or ferric oxides constitutes iron oxides provided for pigments. These may contain impurities of manganese oxides, clay and silica. Oxides of iron remain one of the pigments of natural origin including titanium dioxide. They are highly valued because they possess non-toxic, inert, opaque and weather-resistant properties. Oxides of iron constitute the main component of products in the pharmaceutical industry, paint industry, plastic industry, ink industry and cosmetic industry. Oxides containing mica provide anti-corrosion properties. Natural pigments which qualify for these applications are limited in occurrence. Thus, synthetic iron oxides obtainable from iron compounds have better uniformity, purity of color, consistency and strength. Beneficiation processes of iron ore generate dust in the atmosphere, acid mine drainage in the ecosystem and metallic iron for steelmaking.

The main sources of air contamination during the beneficiation processes are emission of poisonous gases such as nitrous oxide, carbon dioxide, carbon monoxide and sulfur dioxide. Beneficiation process requires dissolution of minerals surrounding the ore and the release of metals and cement matrix into courses of water. These generate acid leading to acid mine drainage. Excess acidity and metal load in the ecosystem result in the loss of ecological balance and health hazards. Therefore, there is a need for valuation of the environmental impact in the planned beneficiation cycle. Sustainable beneficiation is required to reduce its impact on the natural, social or economic environment.

Reduction of heavy metal load from sewages, before their issue to the ecosystem, is a significant problem of contemporary wastewater handling. Ochre and oxides of iron have been used to test the removal of heavy metals including copper and zinc from contaminated aqueous environment. This process is governed by solution pH, metal concentration, ochre (i.e. adsorbent) concentration and contact time of reaction.

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