BIBECHANA
A Multidisciplinary Journal of Science, Technology and Mathematics
ISSN 2091-0762 (online)
Journal homepage: http://nepjol.info/index.php/BIBECHANA

Study on the soil corrosivity towards the buried water supply pipelines in Madhyapur Thimi municipality, Bhaktapur

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Accepted for publication: February 16, 2014

Abstract

This research work is carried out to identify the corrosive nature of soils towards the buried-galvanized steel and cast iron pipelines buried in Sanothimi areas of Madhyapur Thimi municipality, Bhaktapur based on different soil parameters such as organic content, moisture content, pH, resistivity, oxidation-reduction potential, chloride and sulfate ions. The soil parameters of the collected soil samples from the study areas were analyzed using standard ASTM methods. Concentrations of these soil parameters measured in this study were found as: organic content (0.9-7.9%), moisture content (8.0-36.7%), pH (6.8-7.7), resistivity (3900-16700 ohm.cm), oxidation-reduction potential (337-461 mV vs SHE), chloride (25-71 ppm) and sulfate (35-464 ppm) contents. These soil parameters gave an indication of "mildly corrosive" to "less corrosive" nature of soils on the galvanized steels and cast iron pipelines buried in the study areas. Based on the findings of the present studies, it can be advised to the related authorities or local people that simple modification of the soils by using cheapest non-conducting materials like gravel or sand around the buried water supply pipelines before undergrounding them in the study areas is very beneficial from the corrosion point of view to increase their life time.

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Keywords: Chloride & sulfate; Moisture; pH; Resistivity; Oxidation-reduction potential.

1. Introduction

The study of corrosion behavior of the buried metallic materials in soil is of major importance in corrosion studies, because millions of kilometers of the buried pipelines are used to supply the drinking water, petroleum products and other hazardous chemicals all over the world [1,2]. It was reported that about 0.6% of the water supply pipelines used in USA was replaced due to the corrosion damage by soil each year during 1990s [1]. The USA has over 3.7 million kilometer of pipelines crossing the country transporting natural gas and hazardous liquids from sources to consumers [2]. Similarly, it was reported that about 150,000 Km of ferrous pipelines used to supply the drinking water in Australia were also affected by localized corrosion leading to leaking [3]. In Gutenberg of Sweden alone the water supply system for instance includes a total pipe length of 2000 Km, valued at almost 700 million euro. The water supply pipelines are kept in repair at an annual cost of three million euro; almost 50% of the damage can be related directly or indirectly to soil corrosion [4].

There is a high degree of environmental and economic consequences of soil corrosivity due to a failure of the buried pipelines used to supply the drinking water, natural gas and crude oil all over the world. The corrosion of the buried materials in disturbed soil is mainly influenced by a number of soil parameters like moisture, pH, resistivity, oxidation-reduction potential (ORP), chloride and sulfate contents in soil and so on [5-27], because the soil corrosivity towards the buried materials in an undisturbed soil is generally negligible as compared with that of the disturbed soils [5]. Estimation of these parameters of the disturbed soils can give an indication of their corrosive nature towards the buried pipelines. It was studied the corrosion behavior of galvanized steels, bare steels and zinc metal in different soils of USA [9,10]. It was found that the corrosion of mild steel was increased when the soil moisture content was found more than 60 % [9,10,12,21]. The soil pH below 5 can lead to extreme corrosion of the buried materials by soil and hence soil showing pH 7 is most desirable to minimize the corrosion of the buried materials in soils [5,6]. Therefore, the soil pH ranges from 5 to 8 is not usually considered to be a problem for the corrosion of galvanized steels, cast iron, zinc coatings and so on in soil environments [7,8].

The soil resistivity (reverse of soil conductivity) is historically used as one of the broad indicators for the soil corrosivity towards the buried metallic materials. There is found to be good correlation between the soil resistivity and the corrosion rate of the buried materials. It was reported that the soil resistivity decreased with increasing the moisture content [19]. Hence, the corrosive nature of soil towards the buried materials is increased with increasing the moisture content or decreasing the soil resistivity [10,19]. Consequently, sand and gravel are considered to be less corrosive towards the galvanized steels, because they showed a high resistivity of 6000 ohm.cm or more. On the other hand, clayey and silty soils with the resistivity less than 1000 ohm.cm are generally considered to be highly corrosive for the buried galvanized steels [5,6,28-30].

The measurement of soil ORP is significant to explain the soil corrosivity towards the buried materials, because it determines partially the stability of the materials. On the other hand, soil is generally considered to be “mildly corrosive” if the sulfate and chloride ions are below 200 ppm and 100 ppm, respectively, for soil with pH range between 5–8 and the soil resistivity greater than 3,000 ohm.cm [5-6, 28-30]. In this context, it is meaningful to mention here that the supply of the drinking water from water reservoirs to distribution terminal in Nepal is mostly through the buried-galvanized steels as well as cast iron pipelines, and the study of the corrosion behavior of these buried materials in soil of Kathmandu valley is becoming one of the most importance topics of the underground corrosion [31-36].

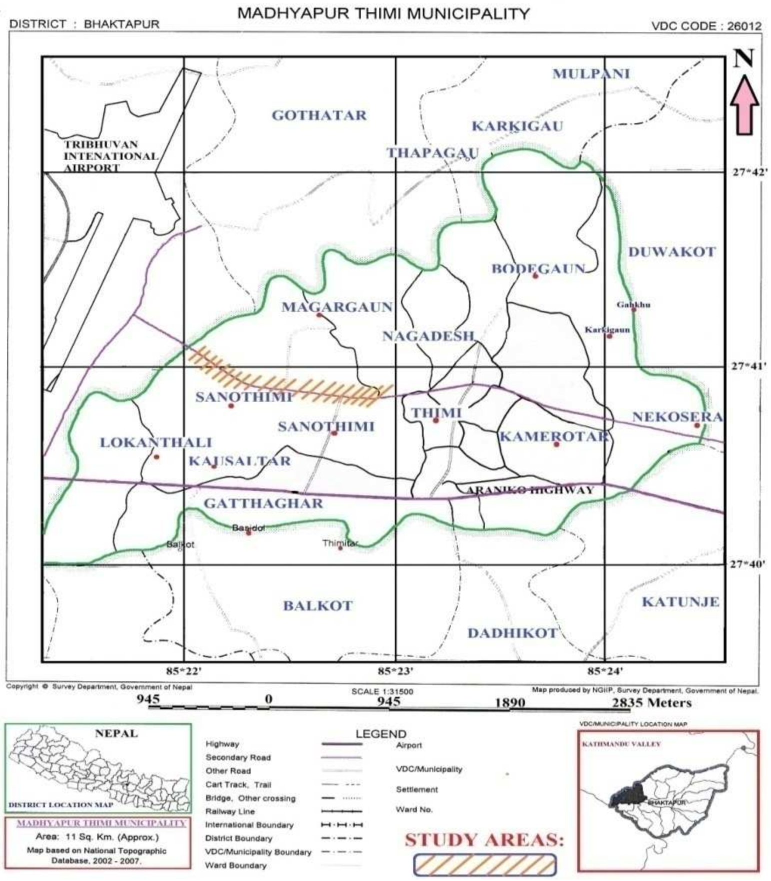
The main objective of the present research work is to study the effects of different soil parameters for corrosivity towards the buried-galvanized steel and cast iron pipelines used to supply the drinking water in Sanothimi area of Madhyapur Thimi municipality of Bhaktapur, Nepal.

2. Materials and Experimental Methods

Total twenty soil samples were collected from Sanothimi area of Bhaktapur, Nepal which is located within the latitude of 27^{o} 40’ 45”-27^{o} 41’ 10” north and the longitude of 85^{o} 22’ 00”-85^{o} 23’ 00” east as shown in Fig. 1(a). Eight soil samples were taken from the depth of about 1 meter from the ground level for the real location of the buried-pipelines used to supply the drinking water in the study area as shown in Fig. 1(b).

To study the effects of depths for soil corrosivity towards the buried metallic materials, twelve more soil samples were also taken from different depths of about 0.25, 0.50, 0.75 and 1.25 meters below the ground level from three sampling sites (i.e., ST2, ST3 & ST8). The soil sample was taken in an air tight polyvinyl bag so that the moisture remained same for a period of moisture content analysis in the laboratory.

Organic content in the soil samples was estimated using hydrogen peroxide treatment method. Moisture content in soil was determined using weight loss method in accordance with the ASTM D4959-07 standards [37]. A 1:2 soil-water suspension of each soil sample was used to determine the soil pH using a digital pH-meter in accordance with the ASTM G51-95 (2012) standards [38]. The conductivity bridge was used to determine the electrical conductivity of a 1:2 soil-water suspension in accordance with the ASTM G187-05 standards [39]. The soil resistivity was calculated from the conductivity. The ORP of the



(a)

(b)

Figure 1: (a) Location and (b) satellite maps of the sampling sites of Sanothimi area of Madhyapur Thimi municipality, Bhaktapur.

soil sample was measured with the help of a digital potentiometer in accordance with the ASTM G200-09 standards [40]. The recorded ORP values vs SCE was converted to reference value of the saturated hydrogen electrode (SHE). A platinum wire and a saturated calomel electrode (SCE) were used as working and reference electrode, respectively. Argentometric titration was used to determine the chloride content in soil. The chloride content in a 1:2 soil-water suspension was determined by titrating the soil suspension against standard silver nitrate solution using potassium chromate as an indicator. Gravimetric method was used to estimate the amounts of sulfate content in soil sample. The details of these methods are discussed elsewhere [31-36].

3. Results and Discussion

3.1 Analysis of parameters of soils collected from the depth of one meter below

It was found that organic and moisture contents in the collected twenty soil samples ranges from 0.9-7.9% and 8-37%, respectively. Among eight soil samples from Sanothimi area of Bhaktapur, the organic contained in five samples was less than 5% while reaming three contained more than 5% and the sample ST-8 contained about 11% organic content as shown in Fig. 2(a). Similarly, one soil sample contained less than 10%, three samples contained 10-20% and remaining four samples contained 21-40% moisture content among eight soil samples collected from the depth of 1 m below the ground level as shown in Fig. 2(b). These results revealed that 50% of the soil samples (4 out of 8 soil samples) are assumed to be "mildly corrosive", while eight samples containing less than 20% moisture content are classified to "less corrosive" for the galvanized steels and cast iron pipes based on the moisture content.

pH is another an important soil parameter that determine the soil corrosivity towards the buried-galvanized steel and cast irons pipelines. The pH value of all eight soil samples collected from study area was in near neutral pH range of 6.8-7.7 as shown in Fig. 2(c). Therefore, these eight soil samples are assumed to be "non corrosive" towards the buried-galvanized steel and cast iron pipelines.

Figure 2(d) shows the results of the soil resistivity of eight soil samples collected from Sanothimi study area. Among these eight soil samples, one has the soil resistivity less than 5000 ohm.cm, four samples have between 5,000-10,000 ohm.cm and remaining three samples showed the resistivity more than 20,000 ohm.cm. It is clearly observed that the soil resistivity is directly correlated with the moisture content in soil samples. The soil samples having high amount of moisture content showed lower value of the soil resistivity as shown in Fig. 2(e). These results revealed that all most all soil samples, except ST-2 are assumed to be "mildly corrosive" to "non-corrosive" nature towards the buried- galvanized steel and cast-iron pipelines based on the classification of the ASTM and NACE standards [28-30]. The ST-2 soil is assumed to be "moderately corrosive" and is more corrosive than those other seven soils.

The ORP value of all eight soil samples of the study area was in the range of 337 to 451 mV vs SHE. Among these soil samples, three samples have the ORP value in the range of 200-400 mV vs SHE and remaining five soil samples have the ORP value more than 400 mV vs SHE as shown in Fig. 2(f). These results revealed that all the soil samples are belonged to "non-corrosive" for the buried-structural materials based on the Johe's classification as shown in Table 1 [13,41].

The chloride and sulfate contents in the collected eight soil samples from the study area were found to be in the ranges of 25-71 ppm and 35-229 ppm, respectively, which is shown in Figs 2(g) and 1(h). It was found that all of the soil samples contained less than 100 ppm of chloride which is the upper limit of the chloride content in the soil for showing "mildly corrosive" nature towards the buried galvanized steel as well as the cast iron pipelines as shown in Fig. 2(g). On the other hand, most of the soil samples collected from Sanothimi area, except three samples (i.e., ST-4, ST-7 & ST-8) contained less than 200 ppm sulfate ions which is upper limits of the sulfate content in the soil for showing "mildly corrosive" nature toward the buried-galvanized steel and cast iron pipelines used to supply the drinking water based on the sulfate content results from the present study.

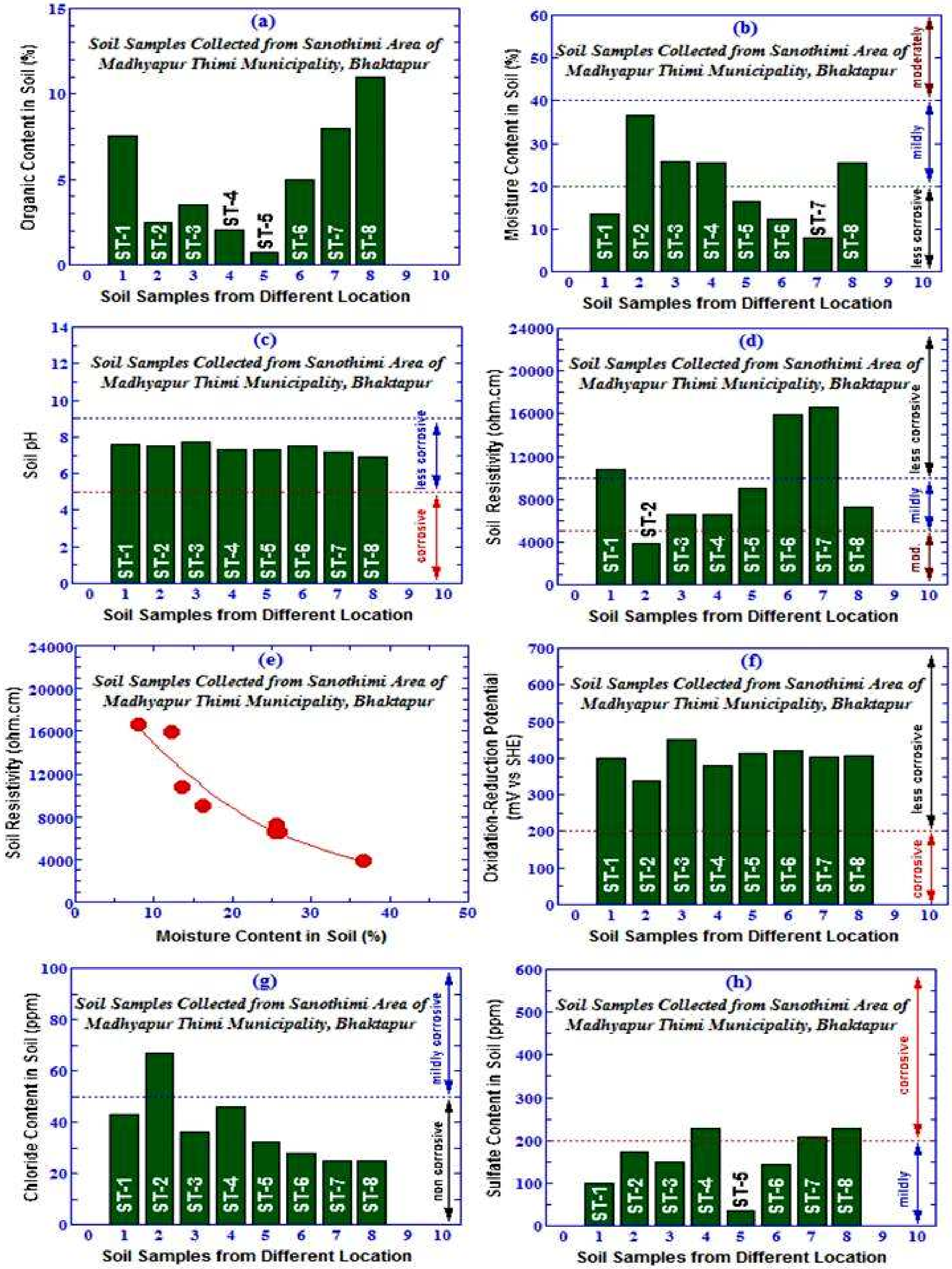


Figure 2: (a) Organic content, (b) moisture content, (c) soil pH, (d) soil resistivity, (e) moisture content & soil resistivity relationship (f) oxidation-reduction potential (g) chloride content and (h) sulfate content in each soil samples collected from Sanothimi area of Bhaktapur, Nepal.

Table 1: Relationship between different soil parameters and soil corrosivity towards the buried materials.

Soil Parameter	Soil Corrosivity
1. ***Soil Resistivity (ohm.cm)[28-30]***	
> 20,000	Essentially Non-Corrosive
10,000-20,000	Mildly Corrosive
5,000-10,000	Moderately Corrosive
3,000-5,000	Corrosive
1,000-3,000	Highly Corrosive
< 1,000	Extremely Corrosive
2. ***Chloride Content (ppm)[28-30]***	
< 100	Mildly Corrosive
3. ***Sulfate Content (ppm)[28-30]***	
< 200	Mildly Corrosive
4. Oxidation–Reduction Potential [13,41] (mV vs SHE)	
>400	Non–Corrosive
201–400	Mildly Corrosive
100–200	Moderately Corrosive
<100	Severe Corrosive

3.2 Analysis of parameters of soils collected from different depths

The effect of soil depths on the soil parameters was carried out to study the corrosive nature of soils of the different depths towards the buried galvanized steel and cast iron pipelines. Fifteen soil samples were collected from different depths of 0.25, 0.50, 0.75, 1.00 and 1.25 meters below the ground level of three sampling sites (i.e., ST-3, ST-4 and ST-8) as indicated in Fig. 1(b). Figures 3(a) to 3(f) summarized the results of organic content, moisture content, pH, ORP, chloride and sulfate contents in soils. In general, the contents of organic matter and moisture in soil samples were increased with increasing the depth of soil sampling part. However, the amount of chloride content is decreased with increasing the soil depths mostly the upper parts of the soil level as shown in Fig. 3(e), probably due to the contamination of some chloride containing pesticides or herbicides in the study areas. On the other hand, there is no effect of depths in soil pH and ORP as shown in Figs 3(c) and 3(d), respectively. But there is no regular pattern of changes of sulfate content with depths soil. Details about such effects will be studied in more soil samples and discussed subsequently.

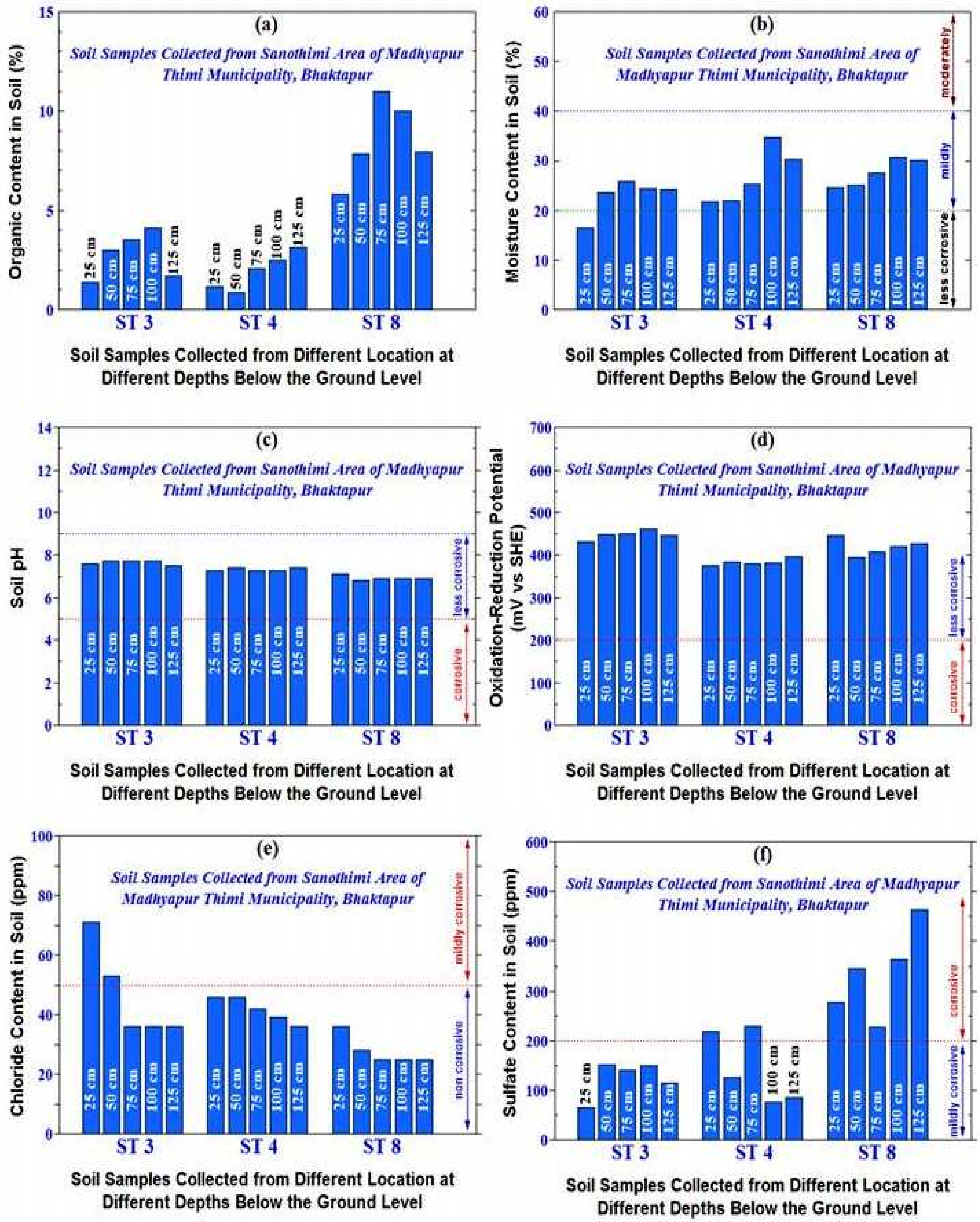


Figure 3: (a) Organic content, (b) moisture content, (c) soil pH, (d) soil resistivity, (e) moisture content & soil resistivity relationship (f) oxidation-reduction potential (g) chloride content and (h) sulfate content in each soil samples collected from Sanothimi area of Bhaktapur, Nepal.

Conclusion

The following conclusions are drawn from the above results and discussion on the corrosive nature of the twenty soil samples collected from Sanothimi area of Madhyapur Thimi municipality, Bhaktapur.

Most of the soil samples of the study area are assumed to be "mildly corrosive" to "less corrosive" towards the galvanized steels and cast iron pipelines buried in the study areas based on the findings of some important soil parameters those affect the buried materials corrosion. Consequently, it can be advised to the local people and government authorities that simple modification of the soils by mixing gravel or sand around the buried water supply pipelines before undergrounding them in the study areas is very beneficial from the corrosion point of view to increase their life time.

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