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Original article

Impact of wastewater discharge on the plant diversity, community structure and heavy metal pollution of range plants in eastern Saudi Arabia

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ABSTRACT

The main objectives of this study were to determine the floristic composition of the vegetation cover and to find the effects of wastewater pollution on the plant community structure in eastern Saudi Arabia. 28 stands which were distributed among polluted and unpolluted sites, were chosen for this study. A total of 42 plant species were recorded (14 in the polluted and 28 in the unpolluted sites). The recorded plants comprised of 13 perennial plant species and 29 annual plant species. Seven vegetation communities were determined using TWINSPAN and DCA classification and ordination techniques. Three in the polluted sites, two in the unpolluted sites and the remaining two were mixed communities. The (*Sarcopoterium spinosum – Pistacia len-tiscus*) community in the polluted sites, had the highest values of soil moisture, salinity, sulphate, calcium and potassium. On the other hand, *Juniperus phoenicea – Olea europaea* community in the unpolluted site, had the lowest value of organic matter, salinity and magnesium. In respect of genetic diversity, the community of *Foeniculum vulgare - Nicotiana glauca* in the unpolluted site, was the most diverse, while *Ricinus communis - Chrysanthemum coronarium* in the polluted sites was the least one. Both soil and wastewater heavy metal analysis indicated that Pb, Cd, Cr, Cu and Ni concentrations in the polluted sites were significantly higher than those in the unpolluted ones. The impact of wastewater discharge led to the appearance of new invasive plant species that may significantly affect plant diversity and community structure in eastern Saudi Arabia. Finally wastewater discharge in open rangelands could adversely affect the growth of plant species in the rangelands and thus adversely affect plant community structure and diversity.

1. Introduction

Environmental risks were critical dilemma for most parts of the world. One of these risks is the adverse effects of wastewater disposal. Wastewater contains high concentrations of various kinds of pollutants: The most common pollutants are those that pose harmful impacts to the natural ecosystems such as toxic organic and inorganic materials including different salts, heavy metals, nitrates as well as pathogens (Jaramillo and Restrepo, 2017). Youssef et al. (2011) claimed that wastewater discharge in open areas is a major source of many environmental pollutants.

Biodiversity and rich ecosystems are essential for life on Earth and the preservation of natural resources. However, in recent years, the world faced paramount biodiversity loss and ecosystem deterioration, that adversely affected basics of life (Browne, 2012). Increased industrialization and urbanization in many developing countries boosted the levels of environmental pollutants (Chauhan and Joshi, 2010). The increase in urbanization raised human population, transportation requirements and industrial development. These activities produced more and more high pollutants concentration (Joshi et al., 2009). These pollutants adversely affected plant growth and development (Seyyednejad and Koochak, 2011; Woo et al., 2007).

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In many countries, the increase in urban populations generated huge amounts of wastewater. Due to the limited overall knowledge for wastewater management, these wastewaters is discharged in open areas as well as natural water reservoirs (Scott et al., 2004). Some of these polluted wastewaters is used by municipalities for plant growth and other purposes. In drier regions, such as Saudi Arabia municipal wastewater is reused in irrigation because it is a good reliable source (Organization, 2006). The impact of wastewater on soil pollution is significant and worrying because of its possible r risks to the environment as a whole and attracted substantial alertness (Marques et al., 2009). Soil quality degradation and vegetation abundance reductions are serious outcomes of open wastewater dumping which have led to notable public worry (Ali et al., 2014).

Many research trials indicated the adverse effects of the high heavy metals' concentrations in soil (Balkhair and Ashraf, 2016; Smith, 1996) as these toxic substances would eventually accumulate in growing plant species and surface and underground water.

Lead (Pb) concentration of biological ecosystem is reported by many investigators (Brunetti et al., 2012; Desoky et al., 2020b; Semida et al., 2018). Pb is very toxic and has many chronic health impacts even at concentration. The uptake of Pb might cause mental retardation in children, renal diseases as well as colic anemia. Zinc (Zn) and copper (Cu) are claimed to be toxic to plant species at concentrations lower than those that affect both animals or man Crites (2000).

The influence of wastewater discharge in open rangelands on plant communities naturally growing in these areas in the Kingdom of Saudi Arabia regions has been investigated previously. Considering the foregoing research to deal with the effectiveness of that trend is highly needed. The objectives of the present investigation are formulated to determine the influence of wastewater discharge on open rangelands on the natural vegetation cover in addition to determining the influence of this practice on heavy metal content of plant species in the study area.

2. Material and methods

2.1. Study area

The Eastern region of Saudi Arabia (longitude is 51.14959325120479 and latitude is 23.08889601168289) consists of a broad, flat coastal plain which mainly consists of sandy and gravel soils. The region has a desert climate, with little winter rains and extremely hot temperatures for most of the year. The mean summer maximum temperature around 45 °C, while in the winter, the temperatures are moderate during the day (20 °C) but sometimes fall below freezing during the night. Droughts for 2–4 years are common in the area. The main water source lies 4–120 m below the soil surface, yet the water is highly saline (EC, 12 dsm^{-1}). The coastal areas are characterized by their stressful humidity and high temperature. The northern areas of the eastern region usually receive annually lower than 25 mm of rain, while the southern areas get lower amounts of rain. The coastal areas consist of sandy plains, marshes and subkhat (salt flats) that almost reach the Arabian Gulf. Consequently, the soil surface is shaky in the sites where the water table almost at the soil surface. The coastal areas are mostly having halophytic and xerophytic plant cover. Northwesterly blown sandstorms occur during most of the summer Al-Fredan (2008).

2.2. Sampling

The vegetation of the study area was investigated during the four seasons (2017, 2018, 2019 and 2020) of the year in 10 randomly selected sites, 5 in each of the polluted and unpolluted plots (10 × 10 m each). 28 stands which were distributed among polluted and unpolluted sites, were chosen for this study. A total of 86 plant species were recorded (37 in the polluted and 49 in the unpolluted sites). 23 samples of the various plant species were collected randomly from the wild populations in the 10 studied habitats in the southern Gulf instead of gulf in "Saudi Arabian gulf". In each plot, plant species found were recorded as presence or absence and the cover percent of each was visually estimated. The identification and nomenclature of the recorded plant species were in accordance with (Al-Mutairi et al., 2016; Collenette, 1999). The plant species life forms were determined observed by (Down, 1973) system. The phytogeographical range analysis was performed in accordance with (Zohary, 1973). The specimens were saved in the Herbarium of King Abdul Aziz City for science and Technology (KACST), Al-Muzahmia.

2.3. Municipality wastewater analysis

Wastewater samples were obtained from the municipality effluents that was discharged in open sites. The wastewater samples were collected in plastic bottles and then nitric acid (1 ml HNO3/l) was immediately added to the field before transferring the samples to the lab. The samples were later used for pH, total soluble salts, micronutrients and heavy metal contents using the Official methods of (Horwitz et al., 1970). The results are given in Table 1.

2.4. Plant tissues analysis

All the species were cut from the top 20 cm and the samples were dried at 70 °C in an oven for 48 h and hay yields per plant were weighed, then ground with a Wiley mill to pass a 1 mm screen and analyzed for minerals content. All analyses were carried out on triplicate samples. Macro and microelements were in the plant samples were determined using the Official methods of (Horwitz et al., 1970). 0.5 g of powdered samples of the plant tissues were carefully weighed in a 50 ml standard flask to which 5 ml of concentrated nitric acid was added. The mixture was left to react for 24 h and then the samples were digested on a hot plate and the temperature was gradually increased to 100 °C. When all nitric oxide fumes were expelled, the temperature was raised and stabilized at 150 °C until the mixture was clear. Distilled water was used to dilute the solution. The solutions were then transferred to plastic bottles and labeled. Potassium, calcium, magnesium, manganese, copper, iron and zinc were determined using the Atomic Absorption Spectrophotometer (AA-6650F Shimadzu Japan). Sodium was determined using Flame photometer model Jennway PFP7 (UK). Phosphorus was determined using the UV-1650 (Ps) Shimadzu Japan Spectrophotometer (Page et al., 1982). The final solution for calcium and magnesium estimation contained 1% of Lanthanum Chloride to reduce chemical interference. The final solution for sodium estimation contained 0.1 of potassium chloride (KCl) to control the process of ionization and the amount of manganese, copper, iron and zinc in the original solution were determined by UV-1650 (Ps) s Shimadzu Japan. Following nitric acid digestion, samples were analyzed by direct injection into Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). The concentration of Cd, Cr, Cu, Pb and Ni were determined in accordance to Allen et al. (1986).

2.5. Statistical analysis

One-way analysis of variance (ANOVA) and the least significant difference test were performed to evaluate statistical significance

Table 1
Common plant species in study sites in the eastern region of the Kingdom of Saudi Arabia.

Family	Plant species	Growth habit
Boraginaceae	Arnebia decumbens (Vent) Coss&Kralik	A
	Heliotropium bacciferum Forssk	P
	Heliotropium digynum (Forssk) C. Chr	P
	Moltkiopsis ciliata (Forssk) I.M. Johnst.	A
Caryophyllaceae	Silene arabica Boiss	A
	Anabasis setifera. Moq.	P
	Arthrocnemum macrostachyum (Moric.)	P
	Halocnemum strobilaceum (Pall.) M. Bieb.	P
	Halopeplis perfoliata (Forssk) Asch.	P
	Haloxylon persicum Bunge	P
	Haloxylon salicornicum (Moq.) Bunge ex Boiss	P
	Salsola baryosma (Roem. Et schult) Dandy	P
	Seidlitzia rosmarinus Bunge ex Boiss	P
	Suaeda aegyptiaca (Hasselq) Zohary	A
	Suaeda fruticosa Forssk ex J.E. Gmel	P
	Suaeda vermiculata Forssk ex J.F. Gmel.	P
Compositae	Launaea mucronata (Forssk) Muschl.	A
	Rhanterium eppaposum Oliv	P
Gramineae	Aeluropus lagopoides (L.) Trin. ex	P
	Cutandia memphitica (Spreng) K. Richt	A
	Eragrostis barrelieri Daveau.	P
	Lasiurus scindicus Henrard.	P
	Panicum turgidum Forssk	P
	Pennisetum divisum (J.E. Gmel.) Henrard	P
	Phragmites australis (Cav) Trin.ex Steud.	P
	Stipa capensis Thunb	A
	Stipagrostis plumose (L.) Munro ex T. Anderson	P
Zygophyllaceae	Fogonia indica Burm.F.	A
	Zygophyllum coccineum L.	P
Asclepiadaceae	Leptadenia pyrotechnica (Forssk) Decne	P
Brassiceae	Brassica rapa L	A
Capparidaceae	Dipterygium glaucum Decne	P
Geraniaceae	Monsenia nevia (Decne) Webb	P
Cyperaceae	Cyperus conglomeratus Rottb.	P
Euphorbiacea	Euphorbia granulate Forssk	A
Leguminosae	Alhagi graecorrum Bois graecorum	P
Plantaginaceae	Plantago albicans (Forssk)	A
Polygonaceae	Calligonum comosum (L., Her) Soskov	P
Rosaceae	Neurada procumbens L.	A
Solanaceae	Lycium shawii Roem.et Schult var shawii.	A
Tamaraxiceae	Tamarix arabica Bunge	P
Verenaceae ‘	Avicennia marina (Forssk) Vierh.	P

P = Perennial, A = Annual.

using SPSS software (Software version: **21.0, 20.0, 19.0**) Statistical significance was considered at P < 0.05.

Multivariate analysis was applied in this study: two-way indicator species analysis (TWINSPAN) and the detrended correspondence analysis (DCA) were used respectively for classification and ordination techniques (Hill, 1979a and b). Species richness (alpha-diversity) for vegetation groups was calculated as the average number of species per stand, while species turnover (beta-diversity) was calculated as the ratio between the total number of species recorded in certain vegetation group and its alpha-diversity Whittaker (1972).

3. Results and discussion

A total of 42 plant species were recorded (14 in the polluted and 28 in the unpolluted sites), from the different stands which were distributed among polluted and unpolluted sites, were chosen for this study. The recorded plant species belong to 18 families. The number of perennial plant species was 29 plant species and the number of annual plant species 13 plant species (Table 1). Seven vegetation communities were determined using TWINSPAN. Two communities were recorded in the unpolluted sites, three in the polluted sites and the remaining two were in both. Vegetation groups were named using the 1st and 2nd dominant species. These communities were: 1) *Panicum turgidum-Stipa capensis,* 2) *Pennisetum divisum- Rhanterium eppaposum* in the unpolluted sites, 3) *Avicenna marina- Halopeplis perfoliate*, 4) *Aeluropus lagopoides-Halopeplis perfoliata*, 5) *Tamarix arabica-Aeluropus lagopoides* in the polluted sites, while 6) *Zygophyllum coccineum-Cyperus conglomerates* and 7) *Lasiurus scindicus-, Cyperus* conglomerates were recorded in both.

The plant family *Chenopodiaceae* had the highest number of plant species in the study sites,

The impact of the discharged wastewater on heavy metal contents of the different plant species in the study area was highly significant at the 0.01 probability level (Table 3). The highest values of heavy metals contents in the different plant species were recorded for those growing in the polluted sites (Table 3). The trend of accumulation of heavy metals in the different plant species was Fe > Mn > Cu > Zn > Pb > Ni > Cr > Cd. These results revealed that the discharge of municipal wastewater on the open range land significantly influenced the heavy metal contents of the different rangeland plant species. The high heavy metals content of municipal wastewater could be, while the used in this study the wastewater was actually a mixture of wastewater from different sources including industrial areas and thus contain many different kinds of chemical compounds

Finally from data presented in Fig. 1 showed that 37 plant species were reported in the unpolluted sites and 25 were recorded in the polluted sites. All plant species reported in the polluted sites were perennials (Table 2).

There were 42 plant species (perennials and annuals) that belong to 29 genera and 18 families in the polluted and unpolluted study sites (Fig. 1). Chenopodiaceae had the highest number of species with 11 plant species, including one annual (*Suaeda aegyptiaca*) and 10 perennials plant species (Table 1) in the study area which was in line with those reported by (Al-Turki et al., 2001)

Table 2
Plant species present in the polluted and Unbolluted sites.

Polluted and/or Unbolluted	**Polluted only**	**Unbolluted only**
Aeluropus lagopoides	Halocnemum strobilaceum	Arnebia decumbens
Alhagi graecorrum	Phragmites australis	Brassica rapa
Anabasis setifera	Stipagrostis plumose	Cutandia memphitica
Arthrocnemum macrostachyum		Euphorbia granulate
Avicennia marina		Fogonia indica
Calligonum comosum		Lasiurus scindicus
Cyperus conglomeratus		Launaea mucronata
Dipterygium glaucum		Leptadenia pyrotechnica
Eragrostis barrelieri		Lycium shawii
Halopeplis perfoliata		Moltkiopsis ciliata
Haloxylon persicum		Monsenia nevia
Haloxylon salicornicum		Neurada procumbens
Heliotropium bacciferum		Plantago albicans
Panicum turgidum		Silene Arabica
Pennisetum divisum		Stipa capensis
Rhanterium eppaposum		Suaeda aegyptiaca
Salsola baryosma		
Seidlitzia rosmarinus		
Suaeda fruticosa		
Suaeda vermiculata		
Zygophyllum coccineum		
Tamarix Arabica		

Table 3
The concentration of heavy metals (mgL^{-1}) in the plant species naturally growing in polluted and unpolluted sites due to the discharge of municipal wastewater in the east coast of Saudi Arabia.

Plant species	sites	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Alhagi graecorrum	Polluted	2.49	3.07	25.4	213.4	73.9	3.47	9.12	19.8
	Unpolluted	0.03	0.004	6.12	12.9	20.7	0.17	0.21	3.57
Anabasis setifera	Polluted	3.61	3.96	21.8	206.8	69.3	2.98	8.76	13.5
	Unpolluted	0.01	0.05	11.7	73.4	25.6	0.02	0.27	4.61
Arthrocnemum macrostachyum	Polluted	4.04	2.96	21.4	205.1	73.8	2.76	5.75	28.8
	Unpolluted	0.023	BDL	9.82	81.5	50.2	0.08	0.23	4.25
Avicennia marina	Polluted	2.55	4.05	21.9	216.7	64.5	2.87	9.10	18.6
	Unpolluted	0.14	0.17	11.2	39.3	40.1	0.06	0.61	5.23
Calligonum comosum	Polluted	1.94	2.96	24.8	214.4	73.4	5.43	9.15	12.3
	Unpolluted	0.24	0.13	11.9	51.9	38.1	0.05	0.75	3.55
Cyperus conglomerates	Polluted	2.38	2.92	27.6	227.2	75.6	2.67	11.4	36.1
	Unpolluted	0.18	0.17	12.8	67.5	28.8	0.18	0.90	4.72
Dipterygium glaucum	Polluted	3.20	3.93	28.5	214.3	70.4	2.18	10.4	26.1
	Unpolluted	0.29	0.11	0.17	51.9	1.69	0.08	0.33	4.69
Eragrostis barrelieri	Polluted	3.61	2.87	26.4	218.5	75.9	1.66	14.9	24.2
	Unpolluted	0.05	0.09	0.23	60.7	1.31	0.07	0.43	1.59
Halopeplis perfoliata	Polluted	3.05	2.74	26.6	230.0	73.3	2.79	9.12	18.6
	Unpolluted	0.03	0.21	0.02	71.3	1.62	0.10	0.56	4.67
Haloxylon persicum	Polluted	3.19	2.80	23.9	217.8	76.5	2.56	8.53	14.3
	Unpolluted	0.04	0.16	0.46	56.7	1.83	0.30	0.48	1.37
Haloxylon salicornicum	Polluted	3.43	2.87	26.4	216.8	69.4	2.87	10.1	8.78
	Unpolluted	0.05	0.35	0.48	57.2	1.24	0.28	0.65	0.79
Heliotropium bacciferum	Polluted	3.29	2.76	24.8	218.3	74.9	2.65	7.13	20.3
	Unpolluted	0.16	0.15	0. 37	54.1	1.94	0.35	0.49	1.59
Panicum turgidum	Polluted	3.71	2.69	19.9	217.3	69.7	1.97	9.71	23.3
	Unpolluted	0.24	0.03	0.29	56.9	1.52	0.08	1.04	2.24
Pennisetum divisum	Polluted	3.39	2.93	24.6	226.6	75.7	3.58	9.09	11.4
	Unpolluted	0.07	0.17	0.09	62.3	1.42	0.09	1.22	1.42
Rhanterium eppaposum	Polluted	3.19	2.92.	25.9	223.6	74.1	1.09	8.10	12.9
	Unpolluted	0.60	0.49	6.94	68.9	23.4	0.03	1.01	2.76
Salsola baryosma	Polluted	3.28	2.56	23.7	227.9	69.2	1.49	7.45	10.8
	Unpolluted	0.55	0.32	5.21	78.2	15.5	0.09	1.00	2.42
Seidlitzia rosmarinus	Polluted	3.52	2.96	23.7	216.7	75.2	1.76	6.89	12.4
	Unpolluted	0.41	0.21	6.73	76.8	12.8	0.02	0.76	1.49
Suaeda fruticosa	Polluted	3.60	2.83	24.1	209.9	70.9	2.68	8.13	10.2
	Unpolluted	0.37	0.26	4.47	68.2	19.1	0.09	0.84	1.21
Suaeda vermiculata	Polluted	3.68	2.63	22.7	218.9	74.1	2.56	7.24	7.08
	Unpolluted	0.66	0.51	1.17	42.3	17.2	0.07	0.92	0.96
Tamarix arabica	Polluted	3.73	2.73	25.0	223.7	69.4	2.89	8.67	3.14
	Unpolluted	0.78	0.37	4.95	56.5	12.9	0.05	0.49	067
Zygophyllum coccineum	Polluted	3.25	2.65	25.4	224.3	68.9	2.43	12.0	4.51
	Unpolluted	0.97	0.51	6.46	65.4	14.7	0.03	0.97	0.78

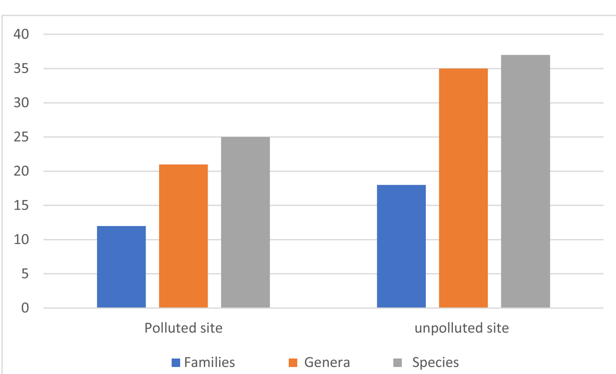

Fig 1. The recorded plant species in the polluted and unpolluted sites in the study area eastern Saudi Arabia.

for the eastern region of Saudi Arabia. These species are: Anabasis *setifera, Arthrocnemum macrostachyum, Halopeplis perfoliate, Halocnemum strobilaceum, Haloxylon persicum, Haloxylon salicornicum, Salsola baryosma, Seidlitzia rosmarinus, Suaeda fruticosa and Suaeda vermiculata*. It was clear from these figures that the polluted sited were less diverged than the unpolluted sited this differed from the findings of (Shaltout et al., 2014) who claimed that the polluted sites were highly diverse in their vegetation cover as compared to unpolluted sites. However, our data were in line with those of (Al-Sodany et al., 2003; Hegazy et al., 2011; Shaltout et al., 2015) who indicated that the vegetation cover in the unpolluted sites were highly diverged as compared to the vegetation cover of the polluted sites. This might be because discharged wastewater increased the salinity level of the soil and most of the plant species present in the polluted sites are those can tolerate high salinity levels such as *Phragmites australis*. Several the plant species present in the study sites cannot tolerate salinity concentration of more than 2.5 ppm (Haller et al., 1974) and higher salinity levels might lead to the termination of their growth. The present study indicated that both salinity and heavy metals content of the discharged municipal drainage water were higher than the upper limit of the USA Environmental Protection Agency (Prevention, 2006). The discharge of these wastewater flourished the growth of salt tolerant plant species and limited the growth of those that are more sensitive to salinity.

Also, Fig. 1 indicated that 37 plant species were reported in the unpolluted sites and 25 were recorded in the polluted sites. All plant species reported in the polluted sites were perennials (Table 2). Shaltout et al. (2014) indicated that the polluted sites showed more plant species diversity that the unpolluted sites, however, this study indicated that the plant species diversity was significantly higher in the unpolluted sites (Table 3).

Haller et al. (1974) reported that soil salinity adversely affects range plant growth. In our study both soil salinity and heavy metals concentration in the studied sites soil might be the detrimental factors in range plants and eventually on plant diversity (Fig. 1). Heavy metal stress leads to decrease in plant production and dangerous health effects Howladar (2014). Its enter into soil by many ways, such as manure and chemical fertilizers, sewage, compost, irrigation with contaminated water, rock phosphate fertilizers, atmospheric precipitation and waste of agricultural industrial (Kadkhodaie et al., 2012). Salinity and heavy metal stresses are of the most serious abiotic stress factors causing environmental problems and limiting growth and crop production (Howladar, 2014). The response to heavy metal stress involves a complicated signal transduction network that is activated by sensing the heavy metals, and is characterized by the synthesis of stress-related proteins and signaling molecules, and finally the transcriptional activation of specific metal-responsive genes to counteract the stress (El-Saadony et al., 2021; Maksymiec, 2007). The common consequence of most abiotic stresses, including salinity (Desoky et al., 2019; Sairam et al., 2005) and heavy metals (Muthuchelian et al., 2001), are an increased production of reactive oxygen species (ROS). These ROS [i.e. superoxide radical (O^-), hydrogen peroxide (H_2O_2), hydroxyl (OH^-)] are extremely toxic to plants. They caused a mage to DNA, proteins, lipids and chlorophyll (Desoky et al., 2020a; Schutzendubel and Polle, 2002). However, plants are well equipped with an antioxidant system consisted of antioxidant enzymes (superoxide dismutase, peroxidase, catalase, glutathione reductase) non- enzymatic low molecule antioxidants (proline, tocopheroles, carotenoids, glutathione, ascorbic acid) to counter the oxidative stress to protect plants from oxidative injuries (Apel and Hirt, 2004). Heavy metal pollutions caused by natural processes or anthropological activities such as metal industries, mining, mineral fertilizers, pesticides, water irrigation and others pose serious environmental problems in present days (Bhaduri and Fulekar, 2012). Heavy metal caught more attention because of their long persistence in soil and cause extremely toxic effects on both the production of crops and on human health due to consumption of crops (Abdo et al., 2020; Bharwana et al., 2013; Elrys et al., 2020). It is well known that Heavy metal toxicity in the environment cause significant toxic effects on plant processes including depression on seed germination (Reddy et al., 2005), disorders in mitosis (Liu et al., 1994), induction of leaf chlorosis (Wierzbicka, 1994), root shoot growth reduction (Elrys et al., 2018; Elrys et al., 2019), enzyme activation and inhibition (Van-Assche, 1990).

The accumulation buildup of heavy metals in the soil would lead to their buildup in the soil solution and so they can easily be uptaken by the growing plant species. These heavy metals would eventually inter the food chain of both range animals and humans. Heavy metals would accumulate to toxic levels that could adversely affect plants, animals and humans (Dotaniya et al., 2017; Rezapour et al., 2019).

4. Conclusion

Based on the results of this study it could be concluded that wastewater discharge in open rangelands could adversely affect the growth of plant species in the rangelands and thus adversely affect plant community structure and diversity. The buildup of heavy metal concentration due municipal water disposal can negatively affect the whole ecosystem and eventually enter human's food chain. Legislation must be drawn to forbid the disposal of municipal drainage water in rangelands of the eastern Saudi Arabia.

CRediT authorship contribution statement

Khaled A. Al-Akeel: Conceptualization, Methodology, Software, Data curation, Writing – original draft, Visualization, Investigation, Supervision, Writing – review & editing. **Mohamed A. Al-Fredan:** Conceptualization, Methodology, Software, Data curation, Writing – original draft, Visualization, Investigation, Writing – review & editing. **El-Sayed M. Desoky:** Methodology, Software, Visualization, Investigation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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