# Health Investments and Outcomes: Exploring Global Patterns in Expenditure, Sanitation, and Life Expectancy

In [ ]:

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import re
from datetime import datetime
```

## Loading and Accessing Datasets

In [37]:

```
sani = pd.read_excel("C:\\Users\\navya\\Downloads\\Python_Project\\sanitation da
ghed = pd.read_excel("C:\\Users\\navya\\Downloads\\Python_Project\\GHED all data
expec = pd.read_excel("C:\\Users\\navya\\Downloads\\Python_Project\\life expecta
```

## Cleaning Columns and rows

In [38]:

```
def clean_columns(df):
    df.columns = df.columns.str.strip().str.lower()
    return df

ghed = clean_columns(ghed)
expec = clean_columns(expec)
sani  = clean_columns(sani)
```

In [39]:

```
ghed
```

Out[39]:

| | location | code | region | income | year | pop_size | che_gdp | che_pc_usd | |
|---|---|---|---|---|---|---|---|---|---|
| **0** | Algeria | DZA | AFR | Lower-middle | 2000 | 1 | 3.214854 | 61.857853 | 1.438703e |
| **1** | Algeria | DZA | AFR | Lower-middle | 2001 | 1 | 3.536286 | 67.058594 | 1.622309e |
| **2** | Algeria | DZA | AFR | Lower-middle | 2002 | 1 | 3.441696 | 66.681633 | 1.687023e |
| **3** | Algeria | DZA | AFR | Lower-middle | 2003 | 1 | 3.325694 | 75.951309 | 1.891375e |
| **4** | Algeria | DZA | AFR | Lower-middle | 2004 | 1 | 3.290305 | 92.687630 | 2.179286e |
| **...** | ... | ... | ... | ... | ... | ... | ... | ... | |
| **4401** | Viet Nam | VNM | WPR | Lower-middle | 2018 | 1 | 5.026788 | 161.978714 | 3.523297e |
| **4402** | Viet Nam | VNM | WPR | Lower-middle | 2019 | 1 | 4.974075 | 171.152969 | 3.833619e |
| **4403** | Viet Nam | VNM | WPR | Lower-middle | 2020 | 1 | 4.332198 | 153.101608 | 3.484988e |
| **4404** | Viet Nam | VNM | WPR | Lower-middle | 2021 | 1 | 4.537569 | 168.080338 | 3.851251e |
| **4405** | Viet Nam | VNM | WPR | Lower-middle | 2022 | 1 | 4.588916 | 188.897491 | 4.381836e |

4406 rows × 4121 columns

In [40]:

```
expec
```

Out[40]:

| | ind_id | ind_code | ind_uuid | ind_per_code | dim_time | di |
|---|---|---|---|---|---|---|
| **0** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2000 | |
| **1** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2000 | |
| **2** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2000 | |
| **3** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2000 | |
| **4** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2000 | |
| **...** | ... | ... | ... | ... | ... | |
| **12931** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2021 | |
| **12932** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2021 | |
| **12933** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2021 | |
| **12934** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2021 | |
| **12935** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2021 | |

12936 rows × 15 columns

In [41]:

```
sani
```

Out[41]:

| | data source | world development indicators | unnamed: 2 | unnamed: 3 | unnamed: 4 | unnamed: 5 | unnam |
|---|---|---|---|---|---|---|---|
| **0** | Last Updated Date | 2025-10-07 00:00:00 | NaN | NaN | NaN | NaN | N |
| **1** | NaN | NaN | NaN | NaN | NaN | NaN | N |
| **2** | Country Name | Country Code | Indicator Name | Indicator Code | 1960.0 | 1961.0 | 196 |
| **3** | Aruba | ABW | People using at least basic sanitation service... | SH.STA.BASS.ZS | NaN | NaN | N |
| **4** | Africa Eastern and Southern | AFE | People using at least basic sanitation service... | SH.STA.BASS.ZS | NaN | NaN | N |
| **...** | ... | ... | ... | ... | ... | ... | |
| **264** | Kosovo | XKX | People using at least basic sanitation service... | SH.STA.BASS.ZS | NaN | NaN | N |
| **265** | Yemen, Rep. | YEM | People using at least basic sanitation service... | SH.STA.BASS.ZS | NaN | NaN | N |
| **266** | South Africa | ZAF | People using at least basic sanitation service... | SH.STA.BASS.ZS | NaN | NaN | N |
| **267** | Zambia | ZMB | People using at least basic sanitation service... | SH.STA.BASS.ZS | NaN | NaN | N |
| **268** | Zimbabwe | ZWE | People using at least basic sanitation service... | SH.STA.BASS.ZS | NaN | NaN | N |

269 rows × 69 columns

In [42]:

```
print("GHED columns:", ghed.columns.tolist()[:10])
print("EXPEC columns:", expec.columns.tolist()[:10])
print("SANITATION columns:", sani.columns.tolist()[:10])
```

```
GHED columns: ['location', 'code', 'region', 'income', 'year', 'pop_size', 'che_g
dp', 'che_pc_usd', 'che', 'gghed']
EXPEC columns: ['ind_id', 'ind_code', 'ind_uuid', 'ind_per_code', 'dim_time', 'di
m_time_type', 'dim_geo_code_m49', 'dim_geo_code_type', 'dim_publish_state_code',
'ind_name']
SANITATION columns: ['data source', 'world development indicators', 'unnamed: 2',
'unnamed: 3', 'unnamed: 4', 'unnamed: 5', 'unnamed: 6', 'unnamed: 7', 'unnamed:
8', 'unnamed: 9']
```

# Preprocessing with ghed

In [43]:

```
ghed.isnull()
```

Out[43]:

| | location | code | region | income | year | pop_size | che_gdp | che_pc_usd | che | ggh |
|---|---|---|---|---|---|---|---|---|---|---|
| **0** | False | False | False | False | False | False | False | False | False | Fa |
| **1** | False | False | False | False | False | False | False | False | False | Fa |
| **2** | False | False | False | False | False | False | False | False | False | Fa |
| **3** | False | False | False | False | False | False | False | False | False | Fa |
| **4** | False | False | False | False | False | False | False | False | False | Fa |
| **...** | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| **4401** | False | False | False | False | False | False | False | False | False | Fa |
| **4402** | False | False | False | False | False | False | False | False | False | Fa |
| **4403** | False | False | False | False | False | False | False | False | False | Fa |
| **4404** | False | False | False | False | False | False | False | False | False | Fa |
| **4405** | False | False | False | False | False | False | False | False | False | Fa |

4406 rows × 4121 columns

In [44]:

```
ghed.isnull().sum()
```

Out[44]:

```
location                0
code                    0
region                  0
income                  0
year                    0
                     ...
hk_ext_usd2022_pc    3647
hk_pvtd_usd2022_pc   4029
gdp_usd2022_pc         23
pfc_usd2022_pc         28
gge_usd2022_pc         23
Length: 4121, dtype: int64
```

In [45]:
```
ghed.duplicated().sum()
```

Out[45]:
```
0
```

# with sanitation data

In [46]:
```
sani.isna()
```

Out[46]:

| | data source | world development indicators | unnamed: 2 | unnamed: 3 | unnamed: 4 | unnamed: 5 | unnamed: 6 | un |
|---|---|---|---|---|---|---|---|---|
| **0** | False | False | True | True | True | True | True | |
| **1** | True | True | True | True | True | True | True | |
| **2** | False | False | False | False | False | False | False | |
| **3** | False | False | False | False | True | True | True | |
| **4** | False | False | False | False | True | True | True | |
| **...** | ... | ... | ... | ... | ... | ... | ... | |
| **264** | False | False | False | False | True | True | True | |
| **265** | False | False | False | False | True | True | True | |
| **266** | False | False | False | False | True | True | True | |
| **267** | False | False | False | False | True | True | True | |
| **268** | False | False | False | False | True | True | True | |

269 rows × 69 columns

In [47]:
```
sani.isnull()
```

Out[47]:

| | data source | world development indicators | unnamed: 2 | unnamed: 3 | unnamed: 4 | unnamed: 5 | unnamed: 6 | un |
|---|---|---|---|---|---|---|---|---|
| **0** | False | False | True | True | True | True | True | |
| **1** | True | True | True | True | True | True | True | |
| **2** | False | False | False | False | False | False | False | |
| **3** | False | False | False | False | True | True | True | |
| **4** | False | False | False | False | True | True | True | |
| **...** | ... | ... | ... | ... | ... | ... | ... | |
| **264** | False | False | False | False | True | True | True | |
| **265** | False | False | False | False | True | True | True | |
| **266** | False | False | False | False | True | True | True | |
| **267** | False | False | False | False | True | True | True | |
| **268** | False | False | False | False | True | True | True | |

269 rows × 69 columns

In [48]:

```
sani.isnull().sum()
```

Out[48]:

```
data source                      1
world development indicators     1
unnamed: 2                       2
unnamed: 3                       2
unnamed: 4                     268
                              ... 
unnamed: 64                     21
unnamed: 65                     24
unnamed: 66                     30
unnamed: 67                    268
unnamed: 68                    268
Length: 69, dtype: int64
```

In [49]:

```
sani.duplicated().sum()
```

Out[49]:

```
0
```

# Merging

In [56]:

```
expec = expec.copy()
ghed  = ghed.copy()
```

In [57]:

```
expec['country'] = expec['country'].astype(str).str.strip()
ghed['country']  = ghed['location'].astype(str).str.strip()
```

In [58]:

```
expec['year'] = pd.to_numeric(expec['year'], errors='coerce').astype('Int64')
ghed['year']  = pd.to_numeric(ghed['year'], errors='coerce').astype('Int64')
```

In [59]:

```
print("life: unique countries", expec['country'].nunique(), "years", expec['year
print("ghed: unique countries", ghed['country'].nunique(), "years", ghed['year']
```

```
life: unique countries 196 years 22
ghed: unique countries 194 years 24
```

In [64]:

```
merged_tmp = pd.merge(
    expec,
    ghed.drop(columns=['location'], errors='ignore'),
    on=['country','year'],
    how='outer',
    indicator=True
)

print("\nMerge indicator counts:\n", merged_tmp['_merge'].value_counts())
```

```
Merge indicator counts:
 _merge
both          11715
left_only      1221
right_only      501
Name: count, dtype: int64
```

In [65]:

```
merged_both = merged_tmp[merged_tmp['_merge']=='both'].drop(columns=['_merge']).
print("\nMerged (both) shape:", merged_both.shape)
display(merged_both.head())
```

```
Merged (both) shape: (11715, 4134)
```

| | ind_id | ind_code | ind_uuid | ind_per_code | year | dim_time_ty |
|---|---|---|---|---|---|---|
| **6** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2002 | YE |
| **7** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2002 | YE |
| **8** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2002 | YE |
| **9** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2003 | YE |
| **10** | 90E2E48WHOSIS_000001 | WHOSIS_000001 | 90E2E48 | WHOSIS_000001 | 2003 | YE |

5 rows × 4134 columns

In [94]:

```
clean_df = final_df[keep_cols].dropna()
print("Clean dataset shape:", clean_df.shape)
clean_df.head()
```

```
Clean dataset shape: (9834, 8)
```

Out[94]:

| | country | year | life_expectancy | sanitation | che_gdp | che_pc_usd | gghed_gdp | oo |
|---|---|---|---|---|---|---|---|---|
| **0** | Afghanistan | 2002 | 55.401586 | 22.541339 | 9.443391 | 16.706974 | 0.084181 | 1 |
| **1** | Afghanistan | 2002 | 54.921993 | 22.541339 | 9.443391 | 16.706974 | 0.084181 | 1 |
| **2** | Afghanistan | 2002 | 55.154478 | 22.541339 | 9.443391 | 16.706974 | 0.084181 | 1 |
| **3** | Afghanistan | 2003 | 56.242837 | 24.100333 | 8.941258 | 17.746025 | 0.650963 | 1 |
| **4** | Afghanistan | 2003 | 55.949458 | 24.100333 | 8.941258 | 17.746025 | 0.650963 | 1 |

In [96]:

```
clean_df
```

Out[96]:

| | country | year | life_expectancy | sanitation | che_gdp | che_pc_usd | gghed_gdp |
|---|---|---|---|---|---|---|---|
| **0** | Afghanistan | 2002 | 55.401586 | 22.541339 | 9.443391 | 16.706974 | 0.084181 |
| **1** | Afghanistan | 2002 | 54.921993 | 22.541339 | 9.443391 | 16.706974 | 0.084181 |
| **2** | Afghanistan | 2002 | 55.154478 | 22.541339 | 9.443391 | 16.706974 | 0.084181 |
| **3** | Afghanistan | 2003 | 56.242837 | 24.100333 | 8.941258 | 17.746025 | 0.650963 |
| **4** | Afghanistan | 2003 | 55.949458 | 24.100333 | 8.941258 | 17.746025 | 0.650963 |
| **...** | ... | ... | ... | ... | ... | ... | ... |
| **9832** | Zimbabwe | 2020 | 57.112639 | 35.192362 | 2.954401 | 51.142506 | 0.652689 |
| **9833** | Zimbabwe | 2020 | 59.404763 | 35.192362 | 2.954401 | 51.142506 | 0.652689 |
| **9834** | Zimbabwe | 2021 | 60.533378 | 34.609950 | 2.785717 | 63.511448 | 0.912499 |
| **9835** | Zimbabwe | 2021 | 56.194609 | 34.609950 | 2.785717 | 63.511448 | 0.912499 |
| **9836** | Zimbabwe | 2021 | 58.481022 | 34.609950 | 2.785717 | 63.511448 | 0.912499 |

9834 rows × 8 columns

# Data Exploration and Visualization insights

In [97]:

```
import statsmodels.api as sm
import matplotlib.pyplot as plt
import seaborn as sns

X = clean_df[['sanitation', 'che_gdp']]
y = clean_df['life_expectancy']

X = sm.add_constant(X)
model = sm.OLS(y, X).fit()

print(model.summary())
```

```
                            OLS Regression Results                            
==============================================================================
Dep. Variable:        life_expectancy   R-squared:                       0.652
Model:                            OLS   Adj. R-squared:                  0.652
Method:                 Least Squares   F-statistic:                     9209.
Date:                Wed, 12 Nov 2025   Prob (F-statistic):               0.00
Time:                        01:21:01   Log-Likelihood:                -30124.
No. Observations:                9834   AIC:                         6.025e+04
Df Residuals:                    9831   BIC:                         6.028e+04
Df Model:                           2                                         
Covariance Type:            nonrobust                                         
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const         52.4146      0.163    320.940      0.000      52.094      52.735
sanitation     0.2245      0.002    123.983      0.000       0.221       0.228
che_gdp        0.3389      0.022     15.554      0.000       0.296       0.382
==============================================================================
Omnibus:                     1390.967   Durbin-Watson:                   0.582
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             2655.753
Skew:                          -0.894   Prob(JB):                         0.00
Kurtosis:                       4.812   Cond. No.                         244.
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
```

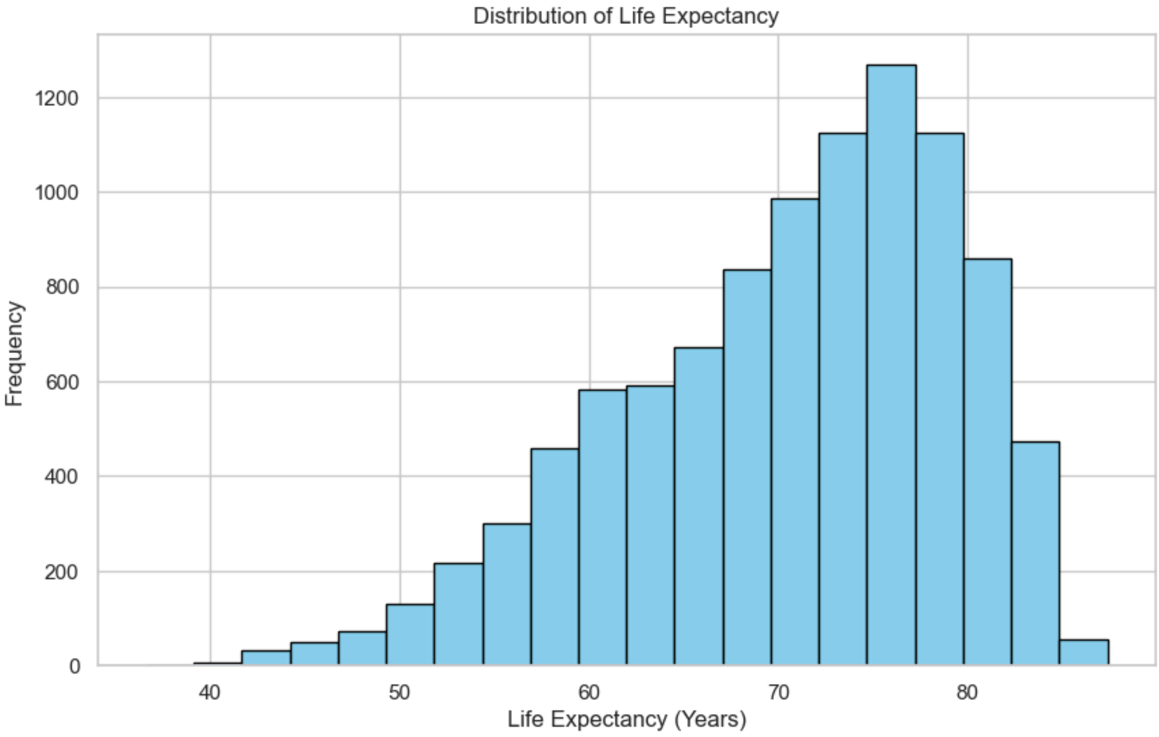
In [99]:

```python
import matplotlib.pyplot as plt
import seaborn as sns

sns.set(style="whitegrid")
```

## Histogram of life expectancy

In [100…

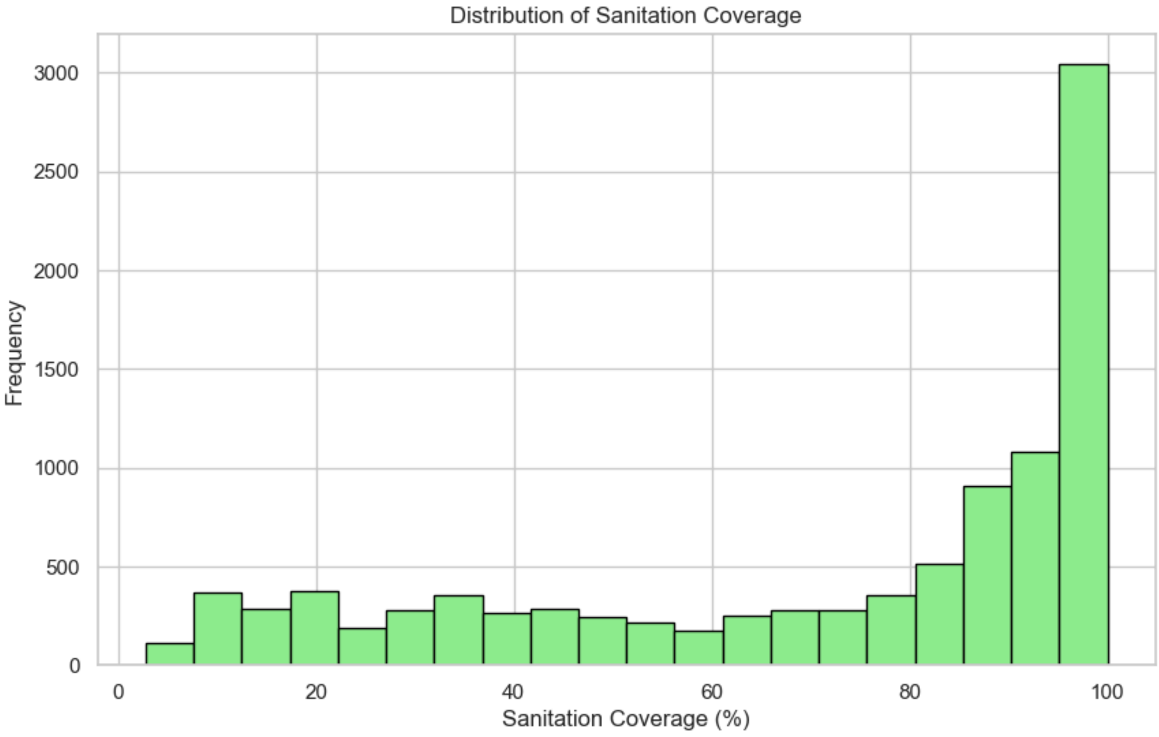
```python
plt.figure(figsize=(10,6))
plt.hist(clean_df['life_expectancy'], bins=20, color='skyblue', edgecolor='black
plt.title('Distribution of Life Expectancy')
plt.xlabel('Life Expectancy (Years)')
plt.ylabel('Frequency')
plt.show()
```



## Histogram of sanitation data

In [101…

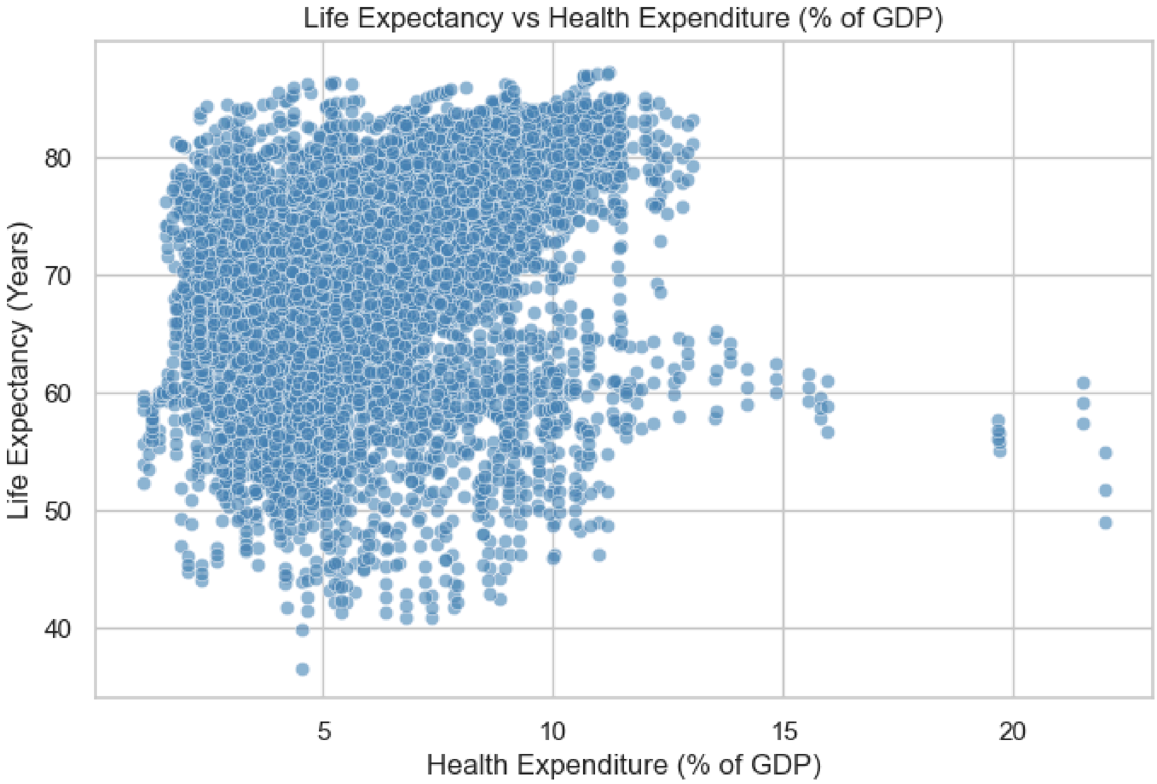
```
plt.figure(figsize=(10,6))
plt.hist(clean_df['sanitation'], bins=20, color='lightgreen', edgecolor='black')
plt.title('Distribution of Sanitation Coverage')
plt.xlabel('Sanitation Coverage (%)')
plt.ylabel('Frequency')
plt.show()
```



## Scatterplot life expectancy vs health expenditure

In [102…

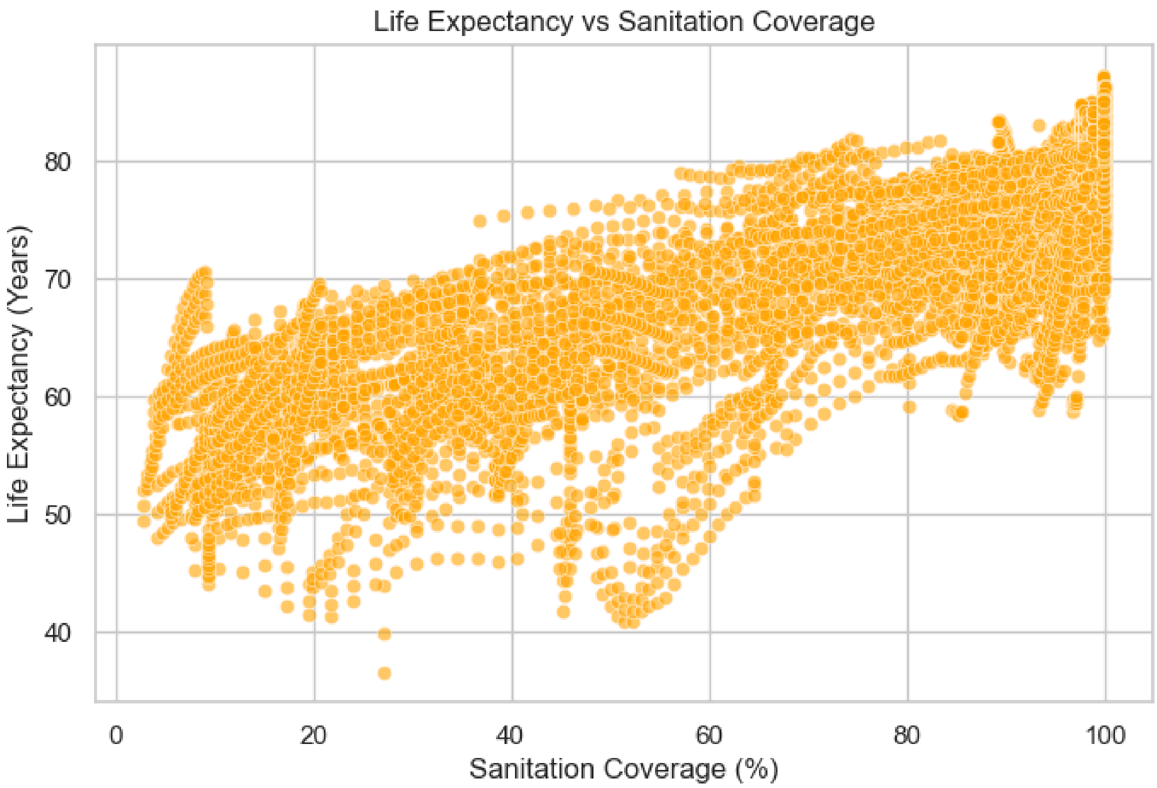
```
plt.figure(figsize=(8,5))
sns.scatterplot(data=clean_df, x='che_gdp', y='life_expectancy', alpha=0.6, colc
plt.title('Life Expectancy vs Health Expenditure (% of GDP)')
plt.xlabel('Health Expenditure (% of GDP)')
plt.ylabel('Life Expectancy (Years)')
plt.show()
```



## Life expentancy vs sanitation data

In [103…

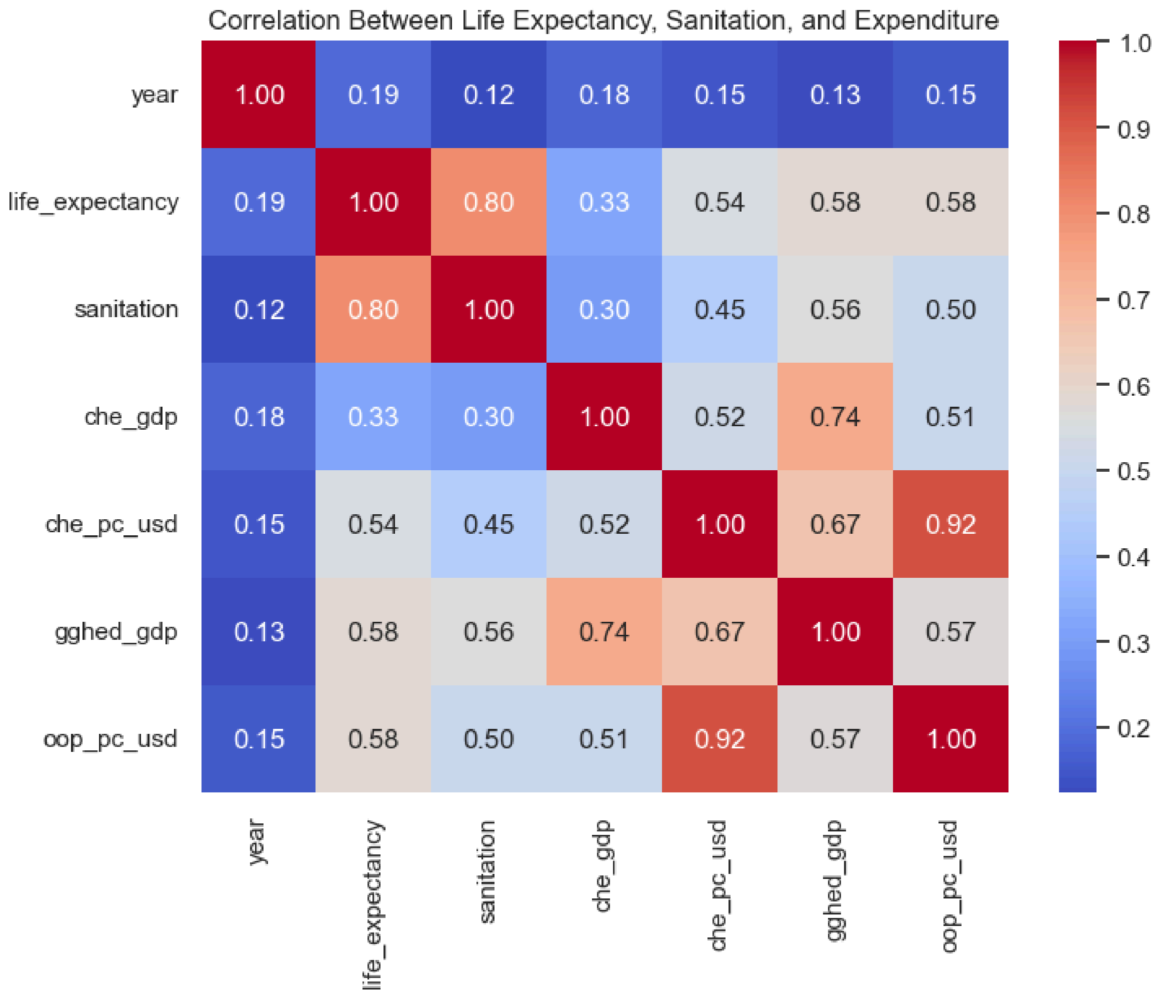
```
plt.figure(figsize=(8,5))
sns.scatterplot(data=clean_df, x='sanitation', y='life_expectancy', alpha=0.6, c
plt.title('Life Expectancy vs Sanitation Coverage')
plt.xlabel('Sanitation Coverage (%)')
plt.ylabel('Life Expectancy (Years)')
plt.show()
```



## correlation heatmap

In [104…

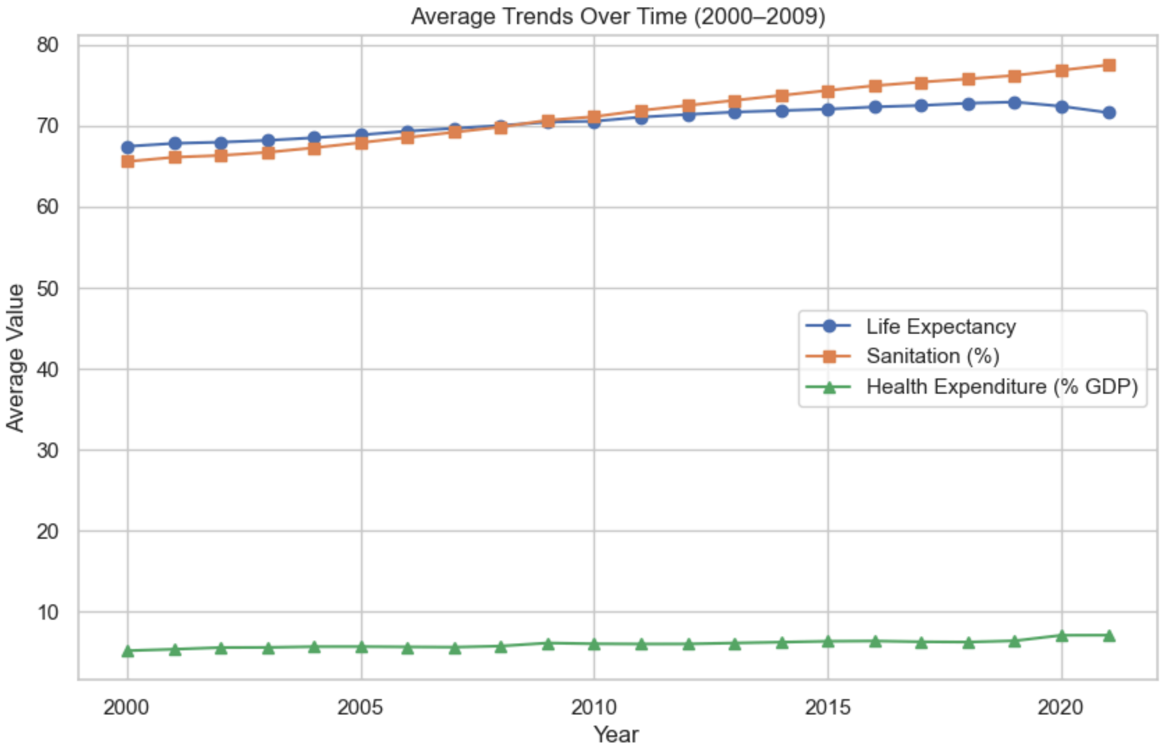
```
plt.figure(figsize=(8,6))
corr = clean_df.corr(numeric_only=True)
sns.heatmap(corr, cmap='coolwarm', annot=True, fmt=".2f")
plt.title('Correlation Between Life Expectancy, Sanitation, and Expenditure')
plt.show()
```



## Trend over time

In [105…

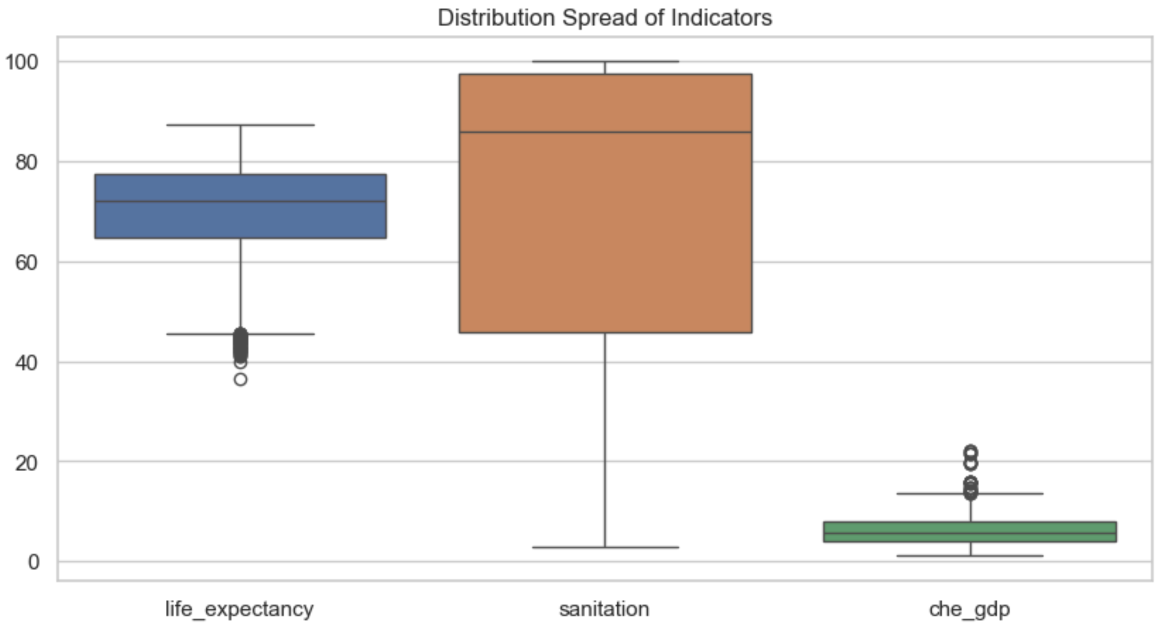
```
trend = clean_df.groupby('year')[['life_expectancy', 'sanitation', 'che_gdp']].m

plt.figure(figsize=(10,6))
plt.plot(trend['year'], trend['life_expectancy'], marker='o', label='Life Expect
plt.plot(trend['year'], trend['sanitation'], marker='s', label='Sanitation (%)')
plt.plot(trend['year'], trend['che_gdp'], marker='^', label='Health Expenditure 
plt.title('Average Trends Over Time (2000-2009)')
plt.xlabel('Year')
plt.ylabel('Average Value')
plt.legend()
plt.show()
```



# Box plot

In [106…

```
plt.figure(figsize=(10,5))
sns.boxplot(data=clean_df[['life_expectancy', 'sanitation', 'che_gdp']])
plt.title('Distribution Spread of Indicators')
plt.show()
```



In [ ]: